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G3N 292 381 383X GB
U1S 1637 G3N

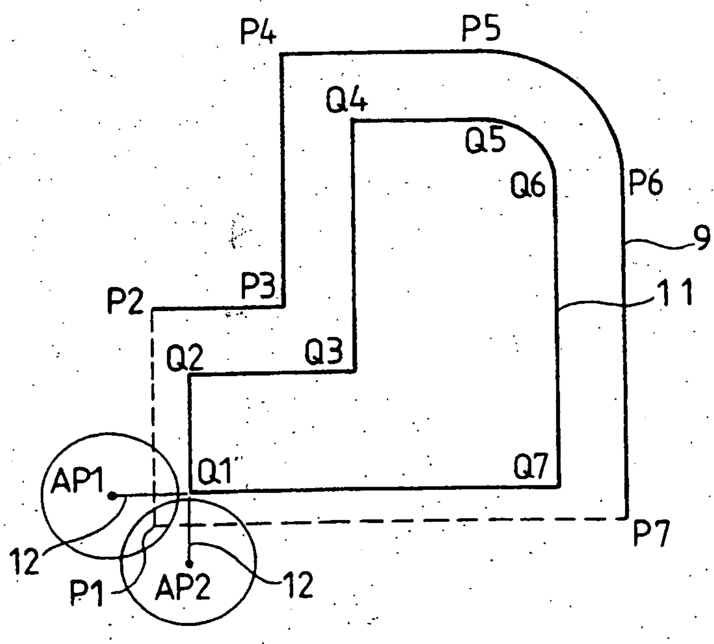
(56) Documents cited
GB A 2176911 EP A 0160096 EP A 0139009

(58) Field of search
G3N
Selected US specifications from IPC sub-class G05B

(54) Numerical control apparatus

(57) To machine along a path $P_1, P_2, P_3, P_4, P_5, P_6, P_7$, an NC control apparatus first produces an offset tool path $Q_1, Q_2, Q_3, Q_4, Q_5, Q_6, Q_7$, the offset being equal to the tool radius for the blocks P_2-P_3-P_4-P_5-P_6-P_7 bounded by the workpiece (wall blocks) but less for the blocks P_7-P_1-P_2 bounded by air (air blocks). The apparatus then calculates an approach/retract path AP1-Q_1, Q-AP_2 for the tool which does not interfere with the workpiece. The approach/retract path desirably joins an air block. Various configurations of approach/retract paths are disclosed for joining various configurations of tool path.

FIG. 10(b)



The drawing(s) originally filed was (were) informal and the print here reproduced is taken from a later filed formal copy.

FIG. 1(a)

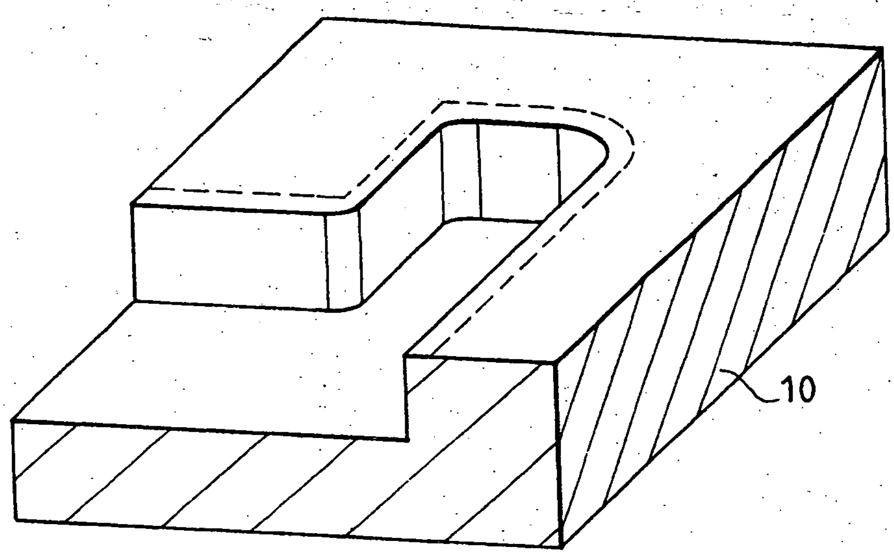


FIG. 1(b)

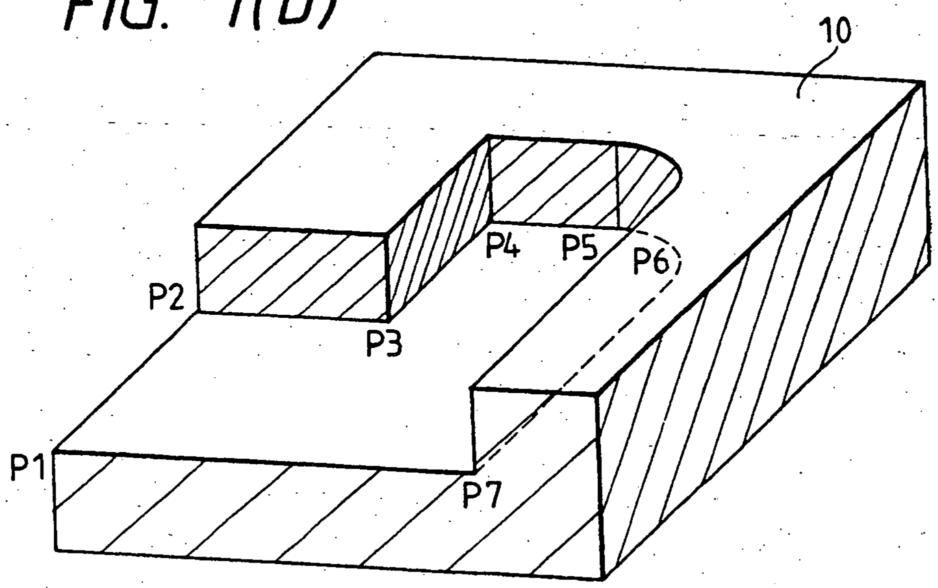


FIG. 2(a)

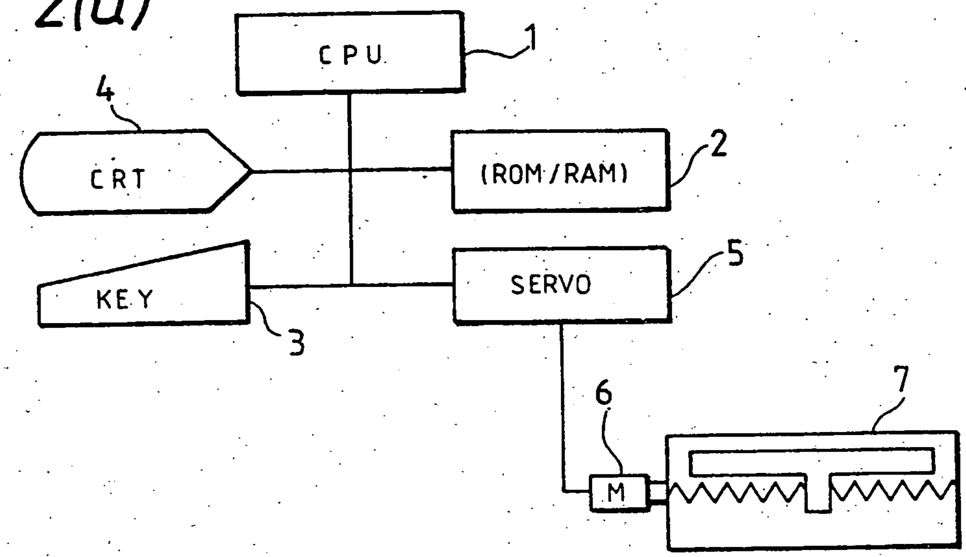


FIG. 2(b)

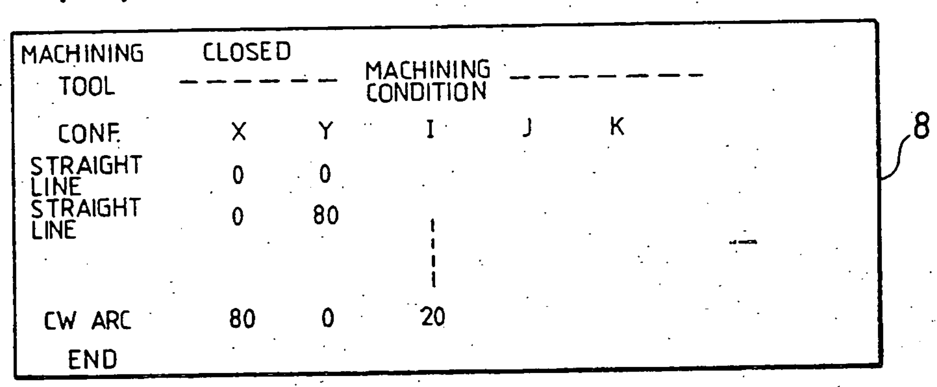


FIG. 2(c)

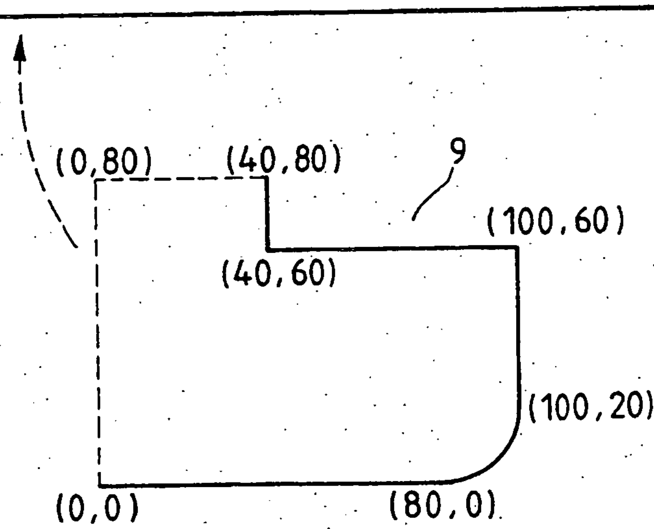


FIG. 3(a)

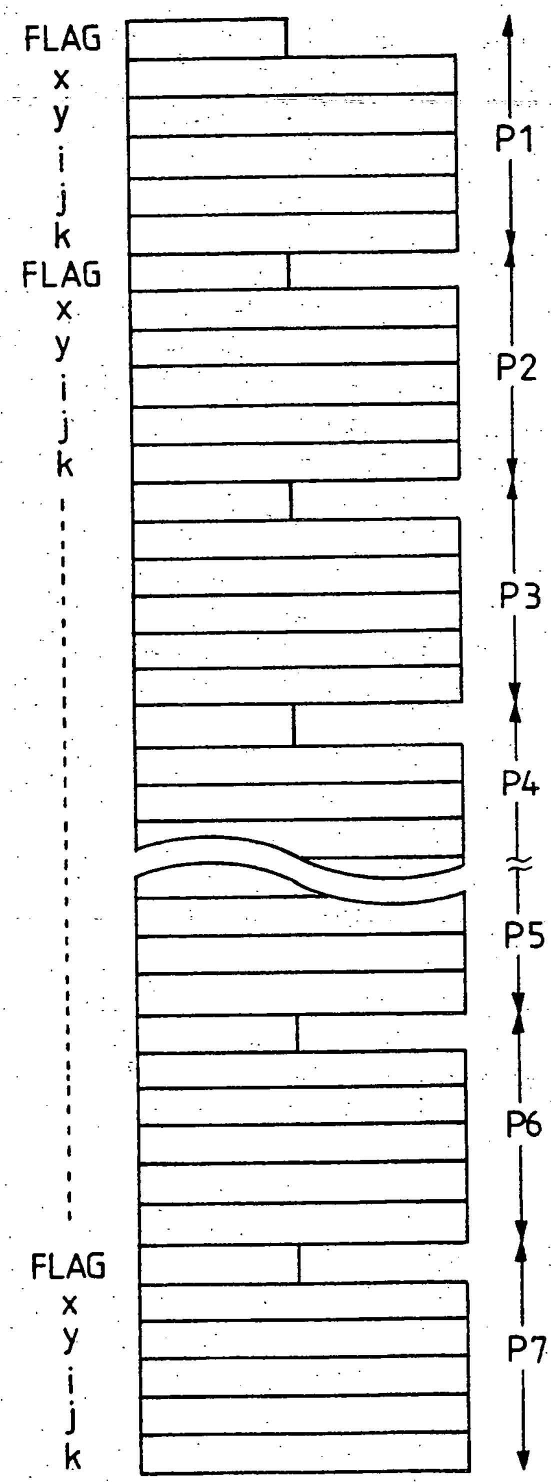

FLAG
x
y
i
j
k
FLAG
x
y
i
j
k
FLAG
x
y
i
j
k
P1
P2
P3
P4
P5
P6
P7

FIG. 3(b)

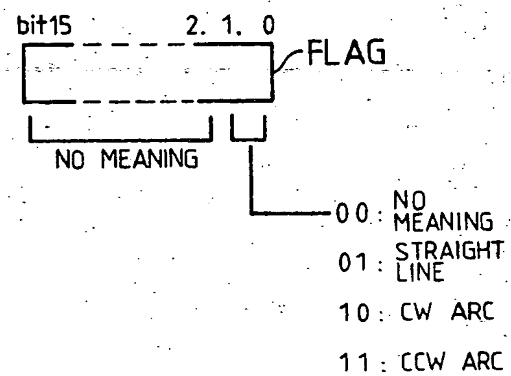

bit15
2. 1. 0
FLAG
NO MEANING
00 : NO MEANING
01 : STRAIGHT LINE
10 : CW ARC
11 : CCW ARC

FIG. 4

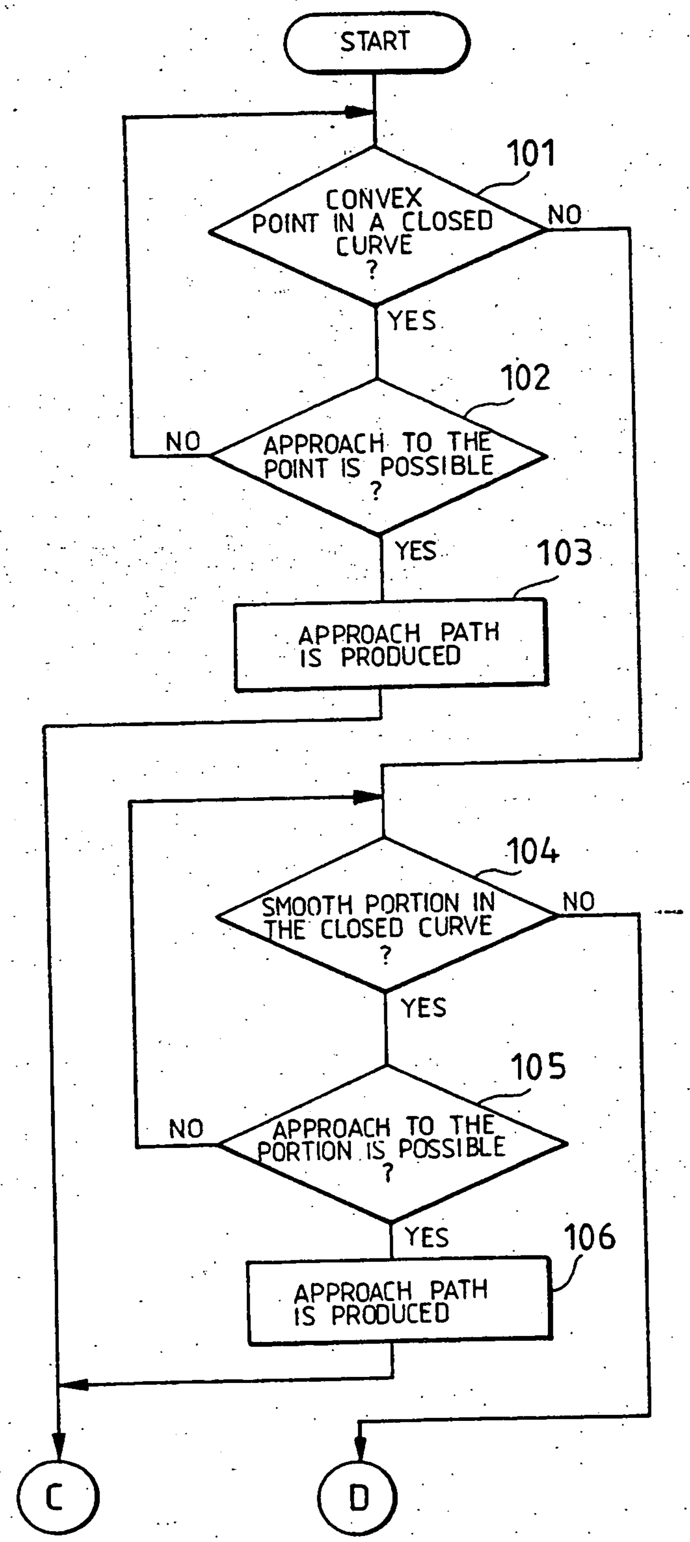

START
101
CONVEX POINT IN A CLOSED CURVE ?
NO
YES
102
APPROACH TO THE POINT IS POSSIBLE ?
NO
YES
103
APPROACH PATH IS PRODUCED
104
SMOOTH PORTION IN THE CLOSED CURVE ?
NO
YES
105
APPROACH TO THE PORTION IS POSSIBLE ?
NO
YES
106
APPROACH PATH IS PRODUCED
C
D

FIG. 5

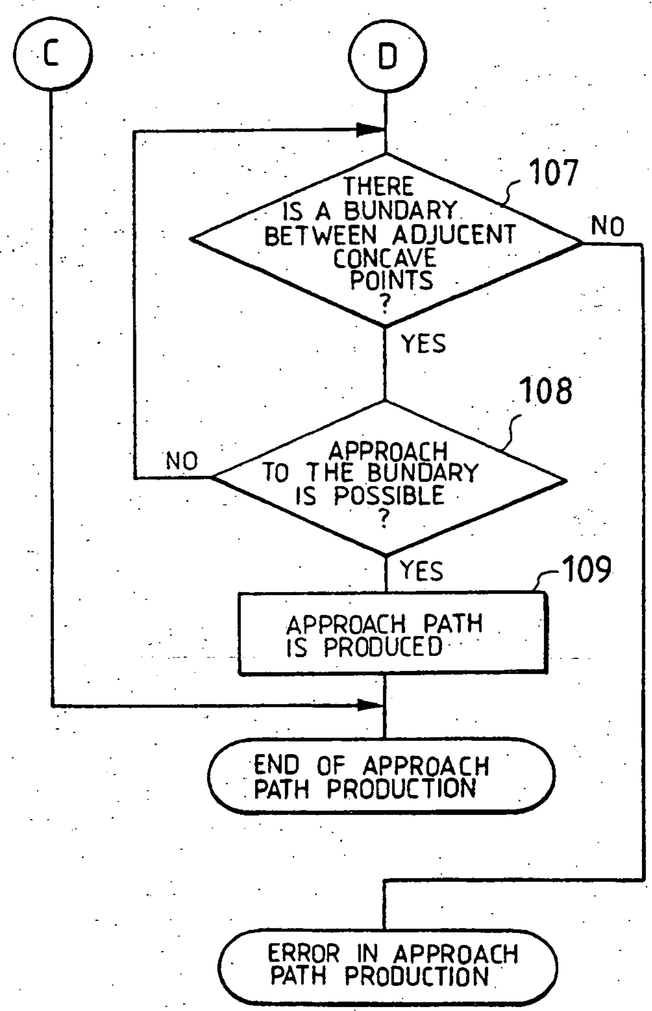

C
D
THERE IS A BUNDARY BETWEEN ADJUCENT CONCAVE POINTS ?
107
NO
YES
108
APPROACH TO THE BUNDARY IS POSSIBLE ?
NO
YES
109
APPROACH PATH IS PRODUCED
END OF APPROACH PATH PRODUCTION
ERROR IN APPROACH PATH PRODUCTION

FIG. 6(a)

TO CONVEX POINT

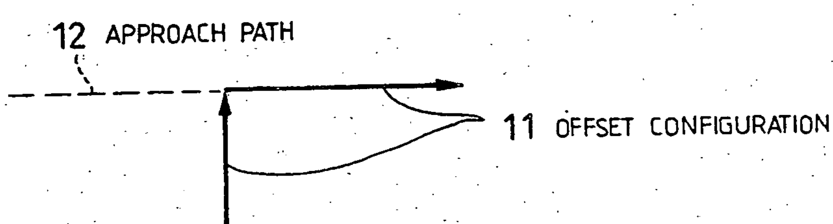


FIG. 6(b)

TO SMOOTH PORTION

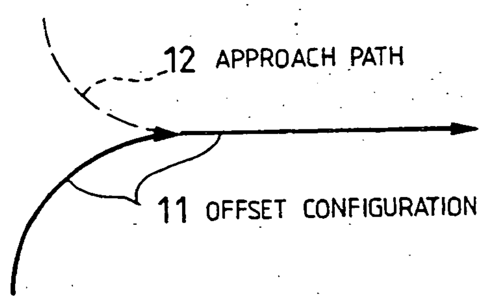


FIG. 6(c)

TO BOUNDARY

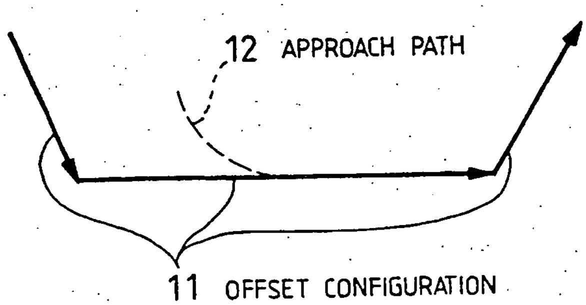


FIG. 7

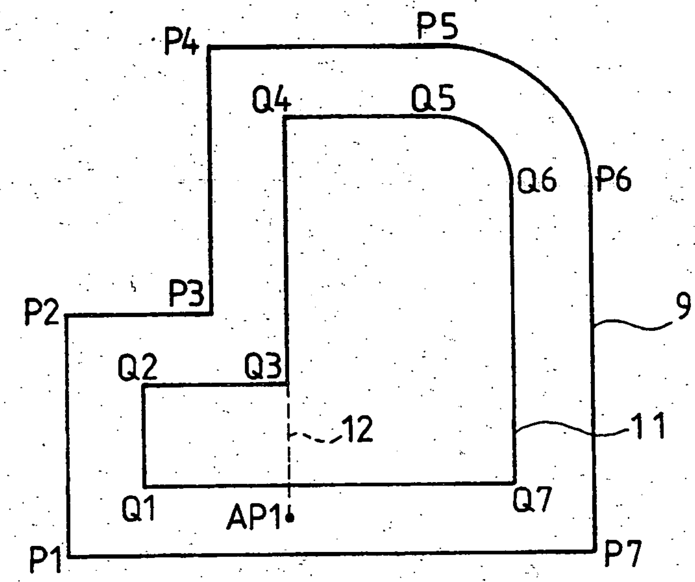


FIG. 8(a)

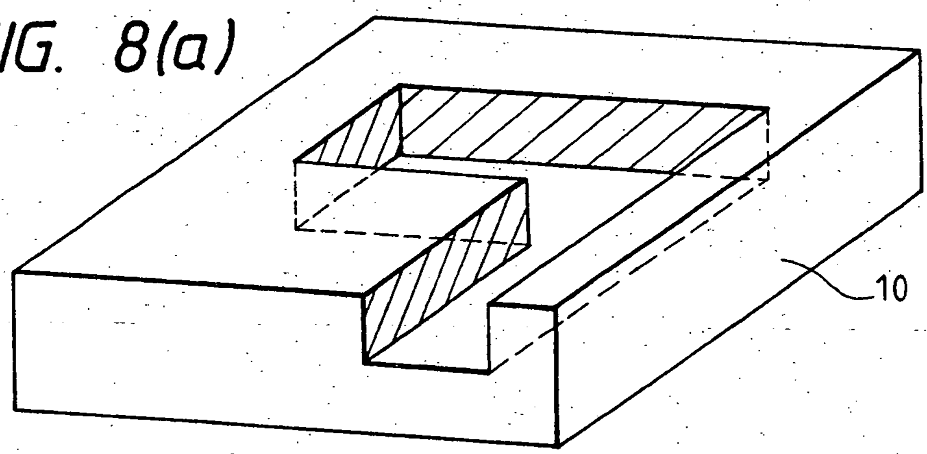


FIG. 8(b)

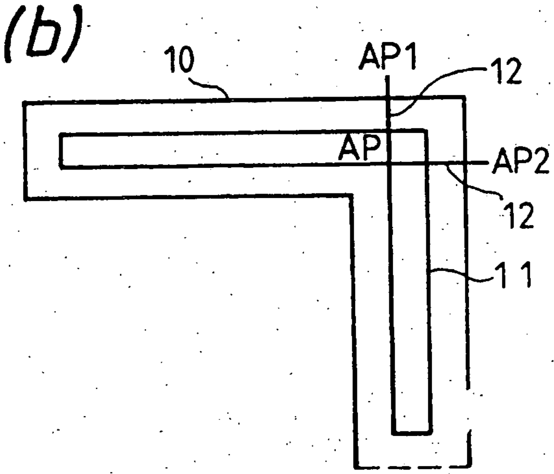


FIG. 9(a)

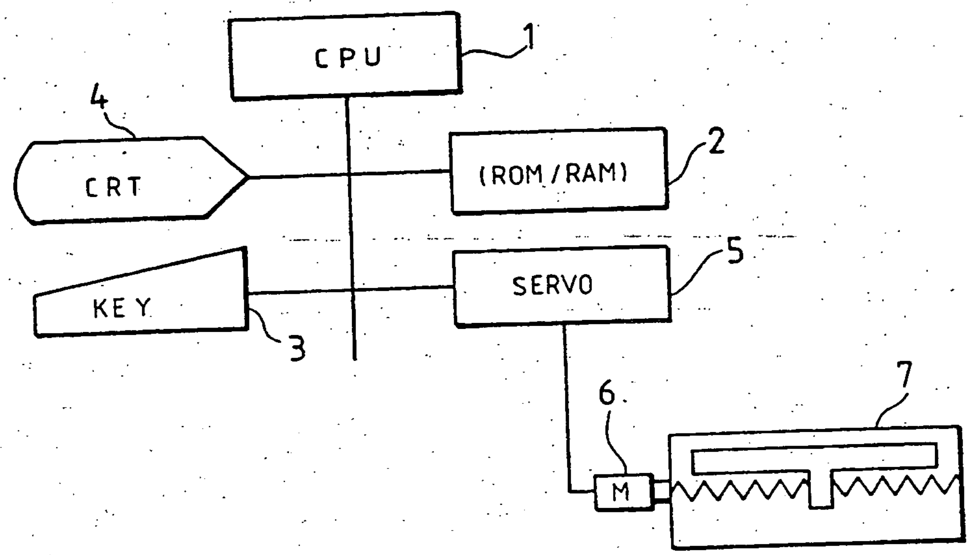


FIG. 9(b)

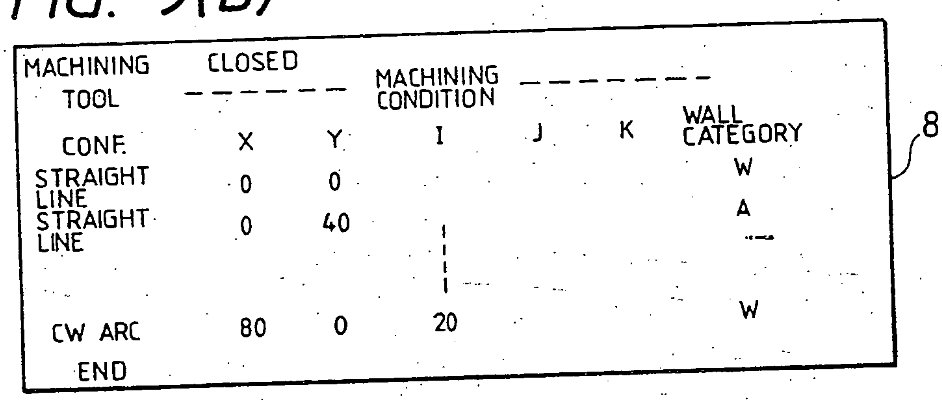


FIG. 9(c)

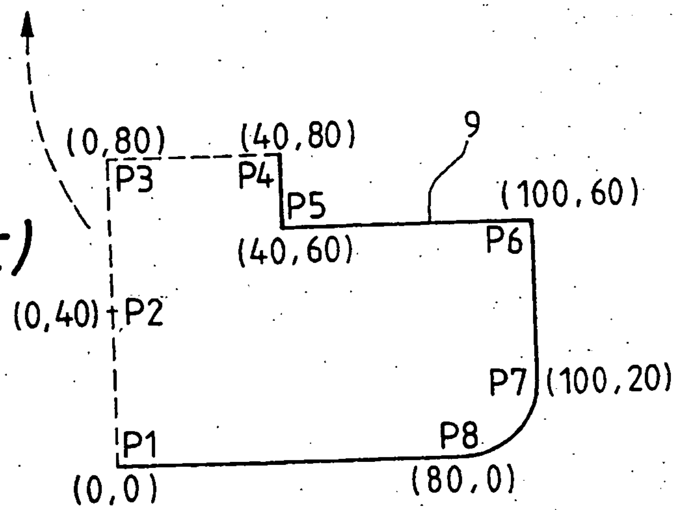


FIG. 10(a)

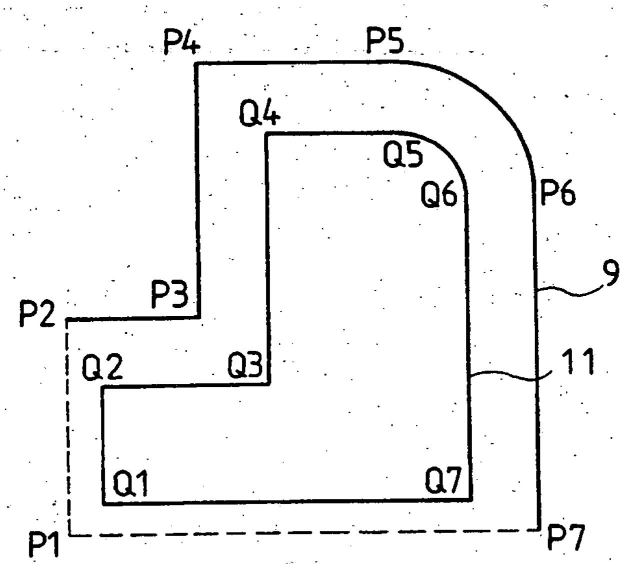


FIG. 10(b)

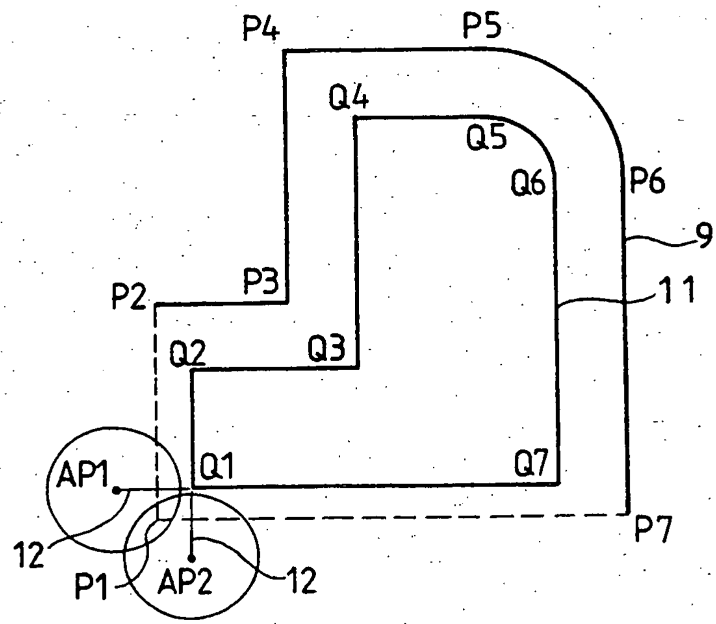


FIG. 11(a)

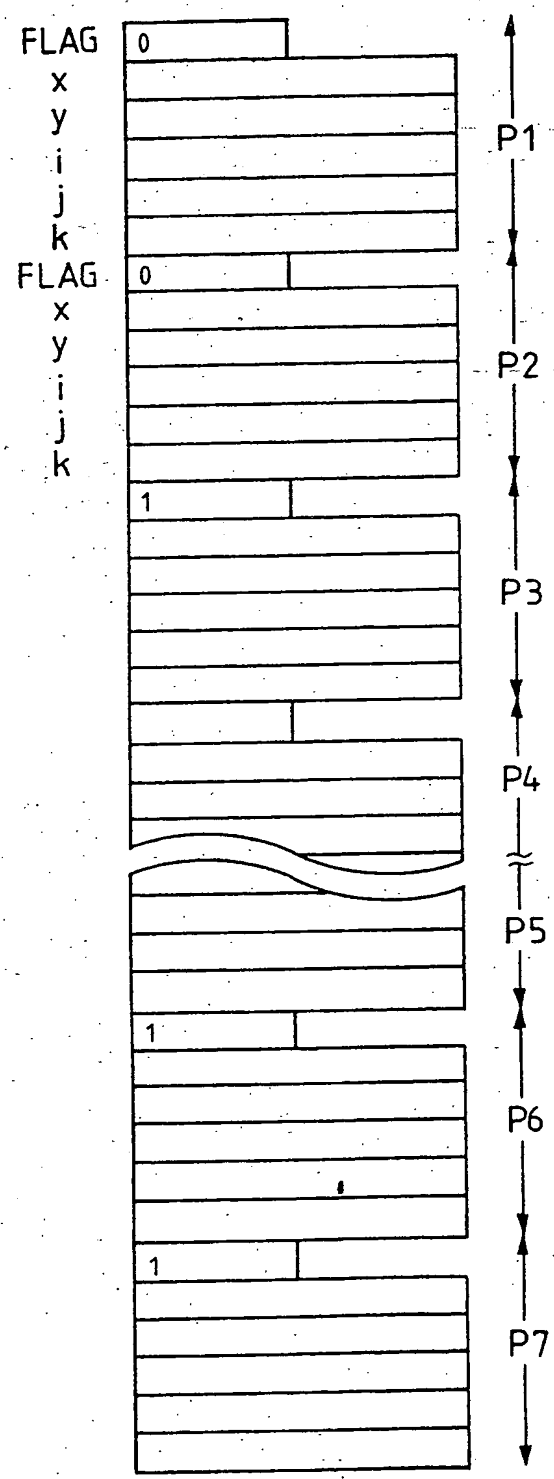


FIG. 11(b)

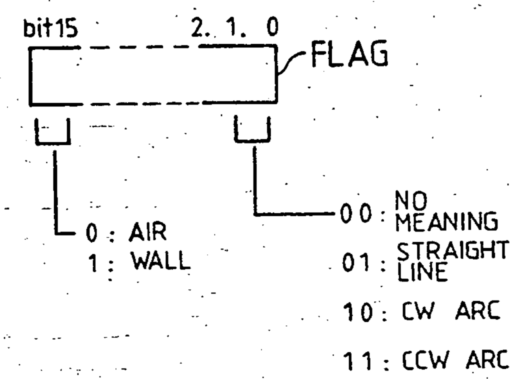


FIG. 12

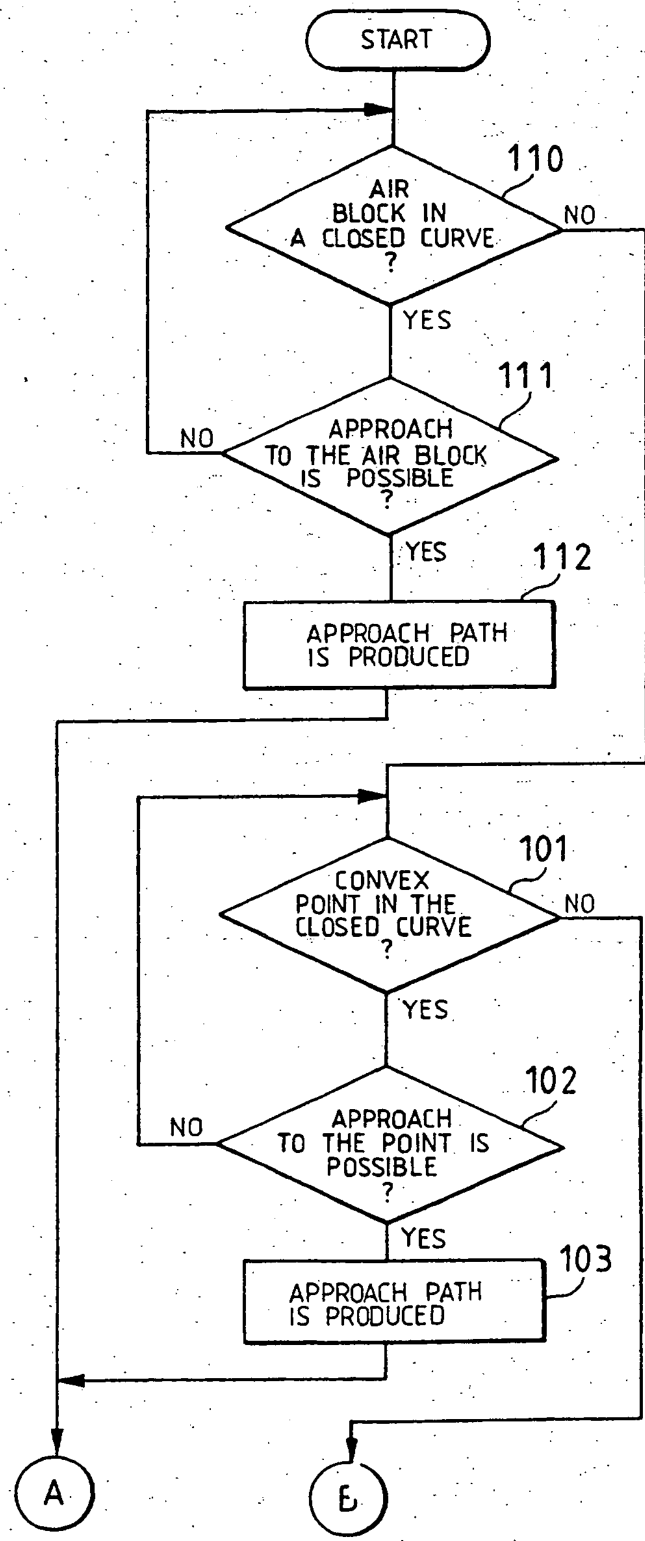

START
110
AIR BLOCK IN A CLOSED CURVE ?
NO
YES
111
APPROACH TO THE AIR BLOCK IS POSSIBLE ?
NO
YES
112
APPROACH PATH IS PRODUCED
101
CONVEX POINT IN THE CLOSED CURVE ?
NO
YES
102
APPROACH TO THE POINT IS POSSIBLE ?
NO
YES
103
APPROACH PATH IS PRODUCED
A
B

FIG. 13

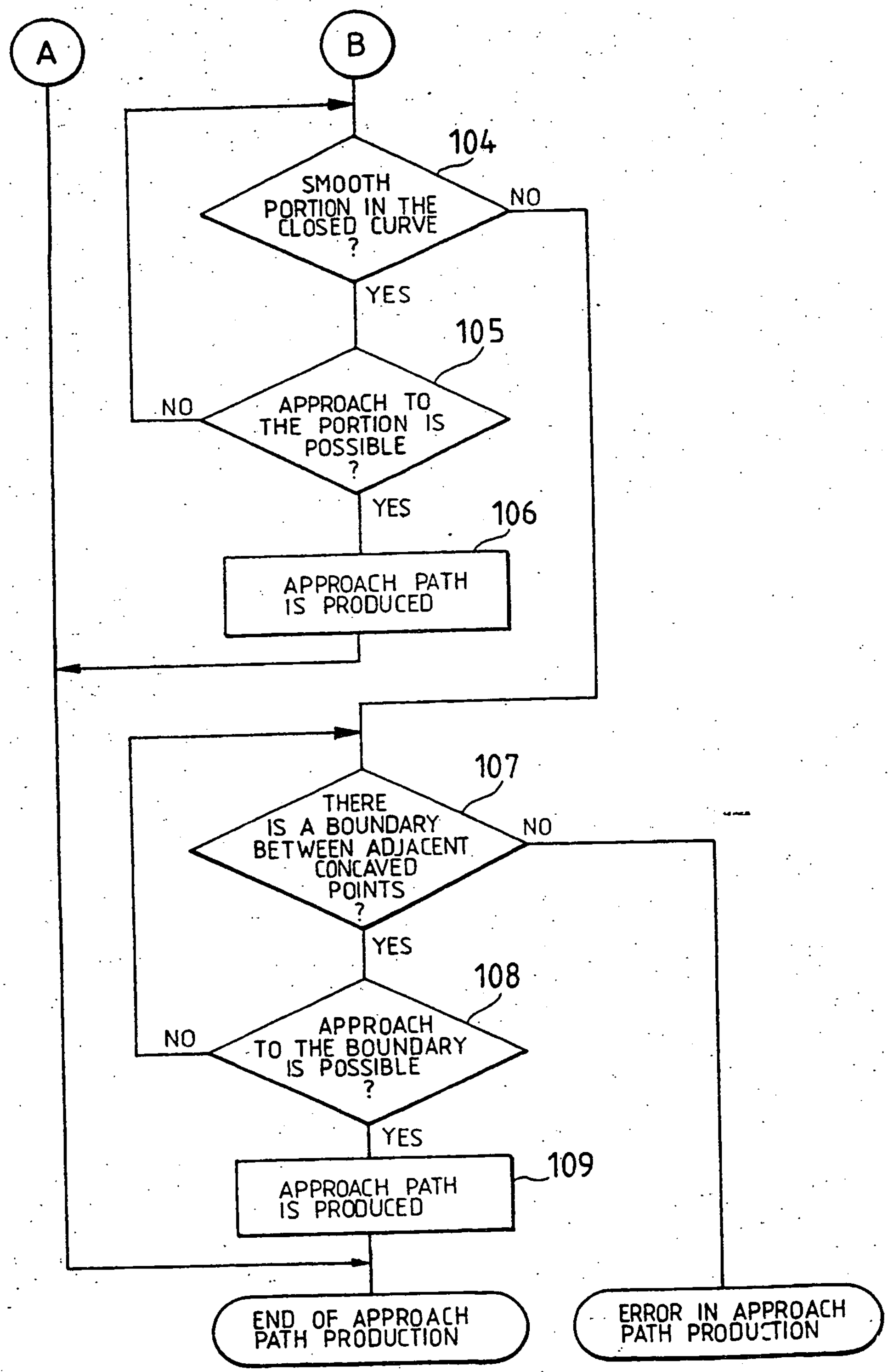

A
B
104
SMOOTH PORTION IN THE CLOSED CURVE ?
NO
YES
105
APPROACH TO THE PORTION IS POSSIBLE ?
NO
YES
106
APPROACH PATH IS PRODUCED
107
THERE IS A BOUNDARY BETWEEN ADJACENT CONCAVED POINTS ?
NO
YES
108
APPROACH TO THE BOUNDARY IS POSSIBLE ?
NO
YES
109
APPROACH PATH IS PRODUCED
END OF APPROACH PATH PRODUCTION
ERROR IN APPROACH PATH PRODUCTION

FIG. 14

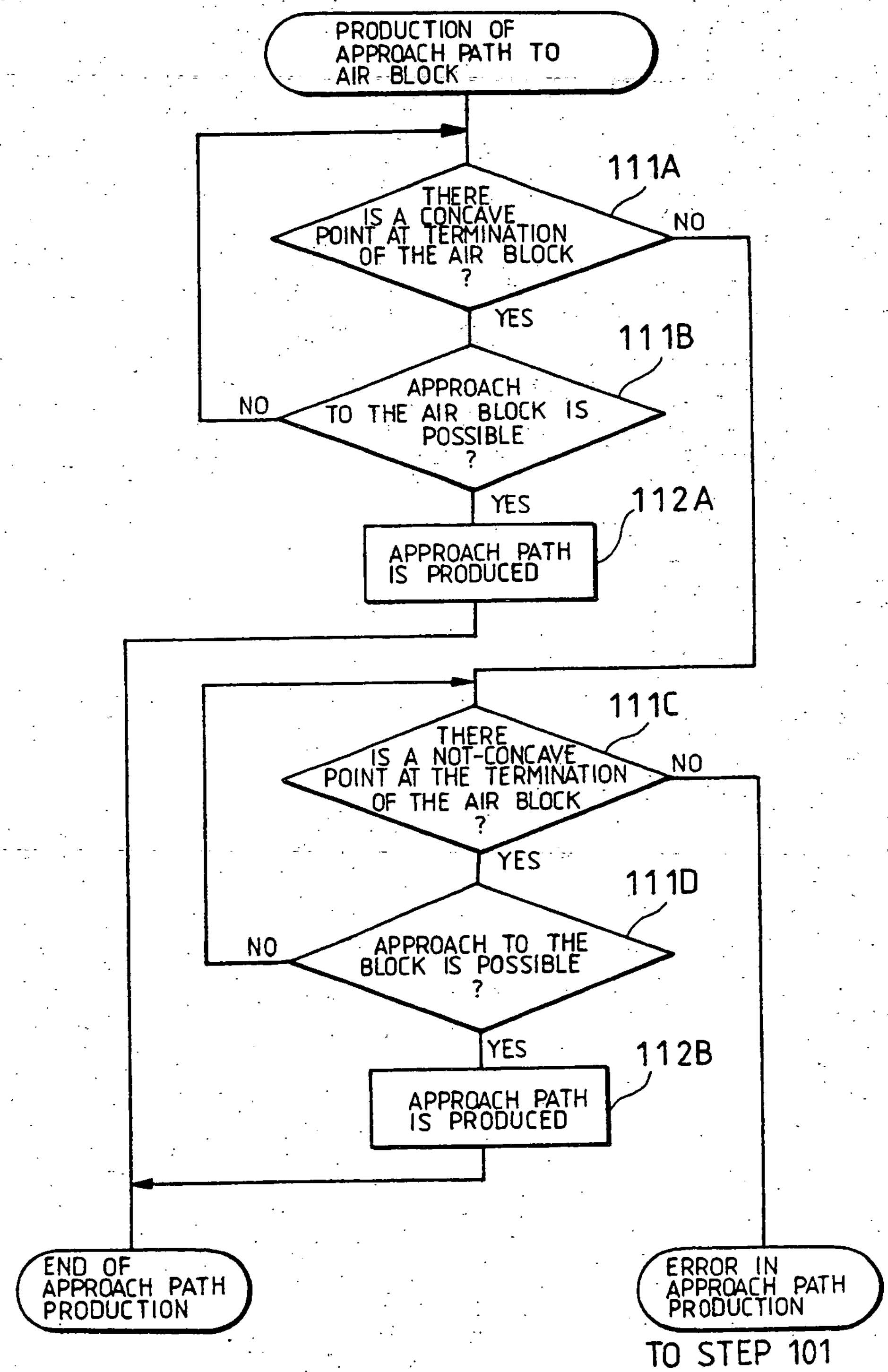

PRODUCTION OF APPROACH PATH TO AIR BLOCK
111A
THERE IS A CONCAVE POINT AT TERMINATION OF THE AIR BLOCK ?
NO
YES
111B
APPROACH TO THE AIR BLOCK IS POSSIBLE ?
NO
YES
112A
APPROACH PATH IS PRODUCED
111C
THERE IS A NOT-CONCAVE POINT AT THE TERMINATION OF THE AIR BLOCK ?
NO
YES
111D
APPROACH TO THE BLOCK IS POSSIBLE ?
NO
YES
112B
APPROACH PATH IS PRODUCED
END OF APPROACH PATH PRODUCTION
ERROR IN APPROACH PATH PRODUCTION
TO STEP 101

FIG. 15(a)

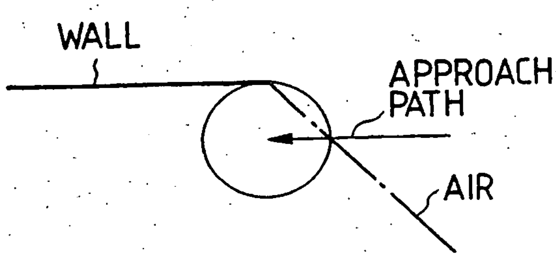


FIG. 15(b)

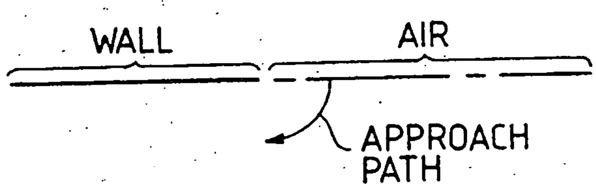


FIG. 15(c)

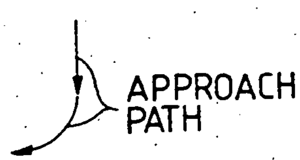


FIG. 15(d)

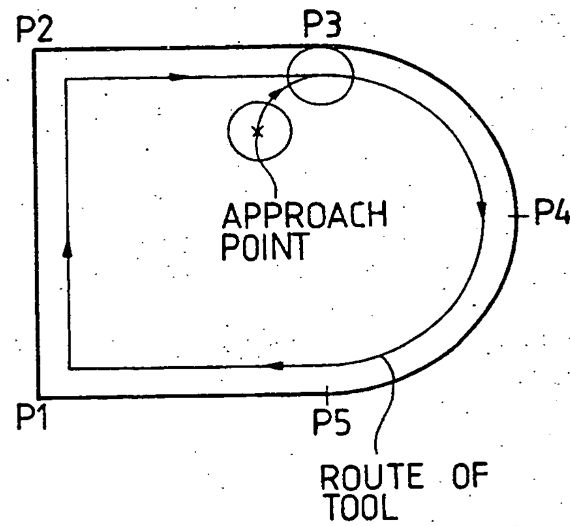


FIG. 15(e)

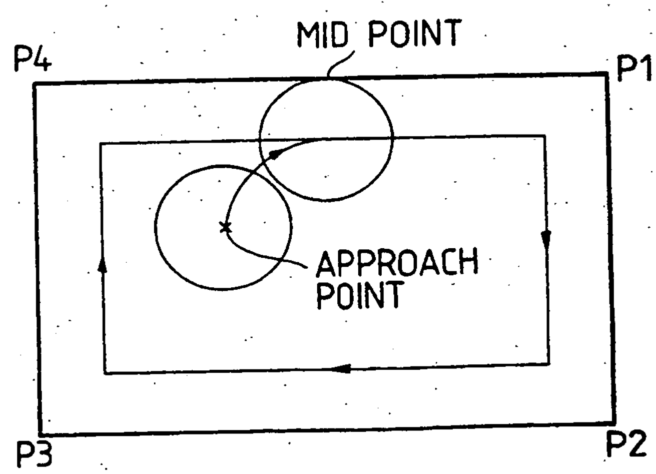


FIG. 16

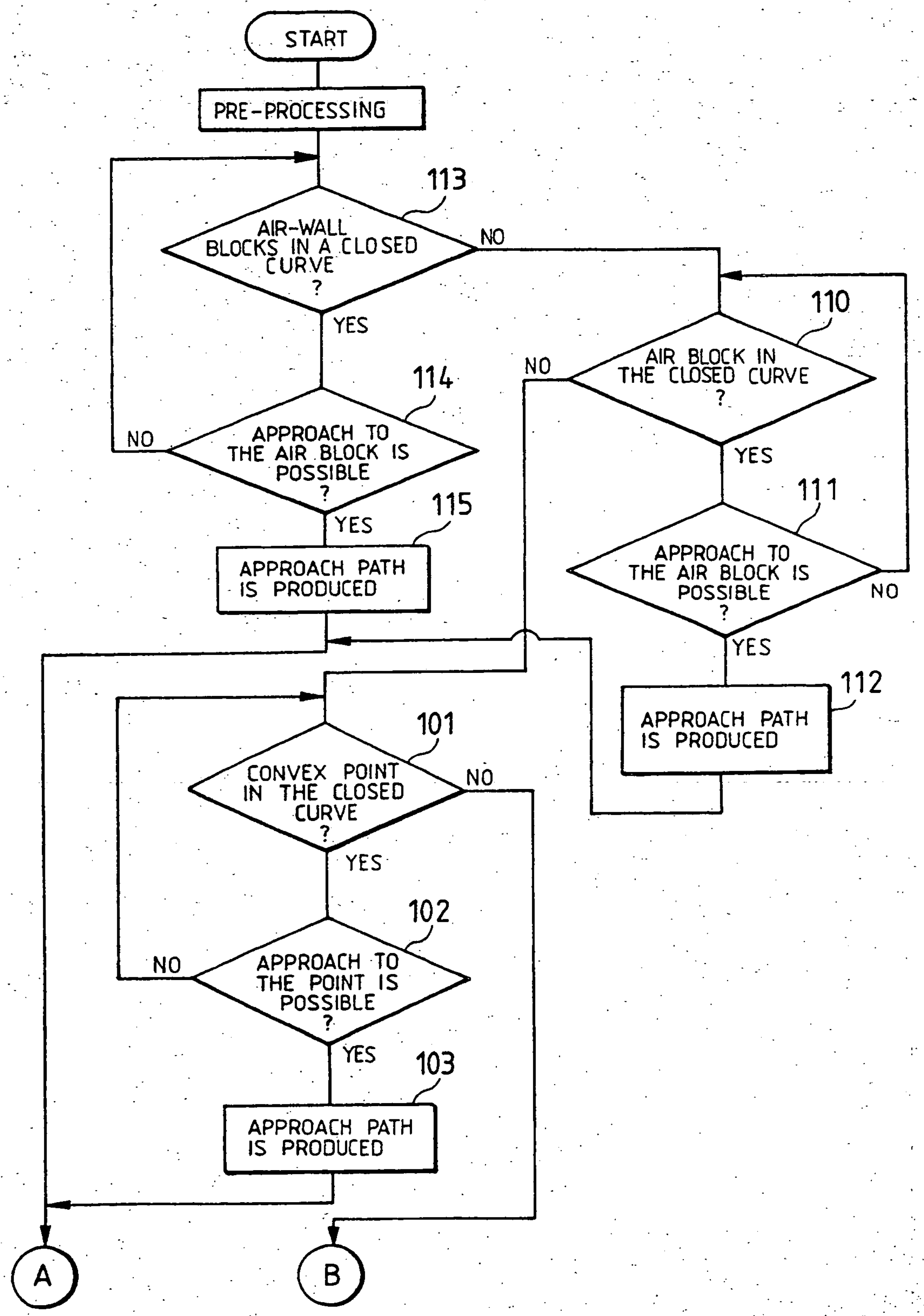

START
PRE-PROCESSING
113
AIR-WALL BLOCKS IN A CLOSED CURVE ?
NO
YES
110
AIR BLOCK IN THE CLOSED CURVE ?
NO
114
APPROACH TO THE AIR BLOCK IS POSSIBLE ?
NO
YES
115
APPROACH PATH IS PRODUCED
YES
111
APPROACH TO THE AIR BLOCK IS POSSIBLE ?
NO
YES
112
APPROACH PATH IS PRODUCED
101
CONVEX POINT IN THE CLOSED CURVE ?
NO
YES
102
APPROACH TO THE POINT IS POSSIBLE ?
NO
YES
103
APPROACH PATH IS PRODUCED
A
B

FIG. 17

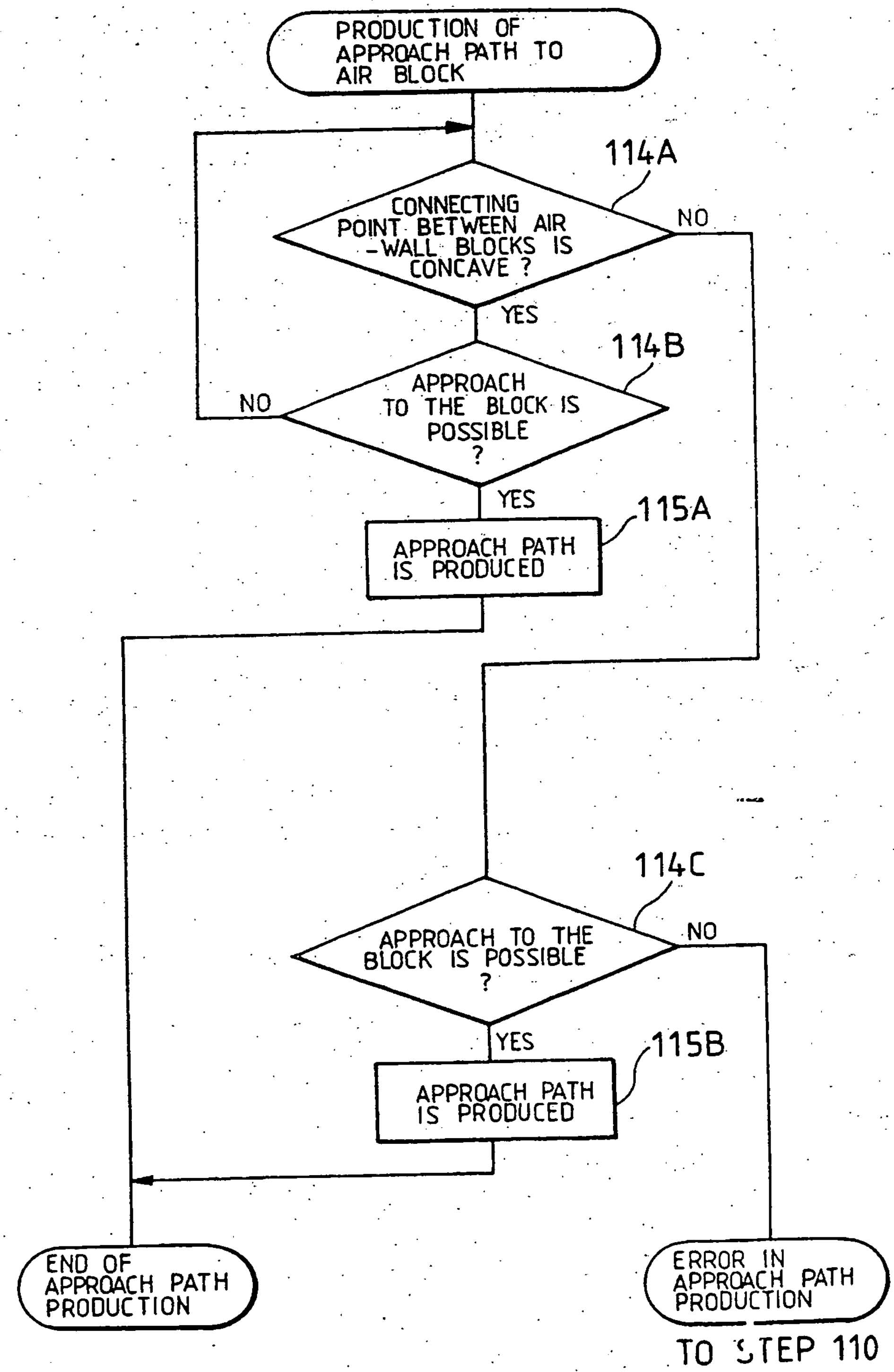

PRODUCTION OF APPROACH PATH TO AIR BLOCK
114A
CONNECTING POINT BETWEEN AIR -WALL BLOCKS IS CONCAVE ?
NO
YES
114B
APPROACH TO THE BLOCK IS POSSIBLE ?
NO
YES
115A
APPROACH PATH IS PRODUCED
114C
APPROACH TO THE BLOCK IS POSSIBLE ?
NO
YES
115B
APPROACH PATH IS PRODUCED
END OF APPROACH PATH PRODUCTION
ERROR IN APPROACH PATH PRODUCTION
TO STEP 110

FIG. 18

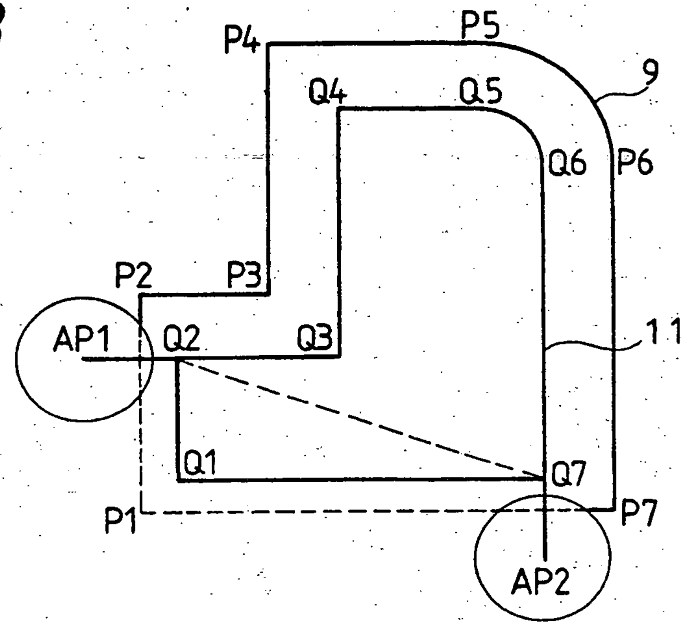

P4
P5
9
Q4
Q5
Q6
P6
P2
P3
AP1
Q2
Q3
11
Q1
Q7
P1
P7
AP2

FIG. 20

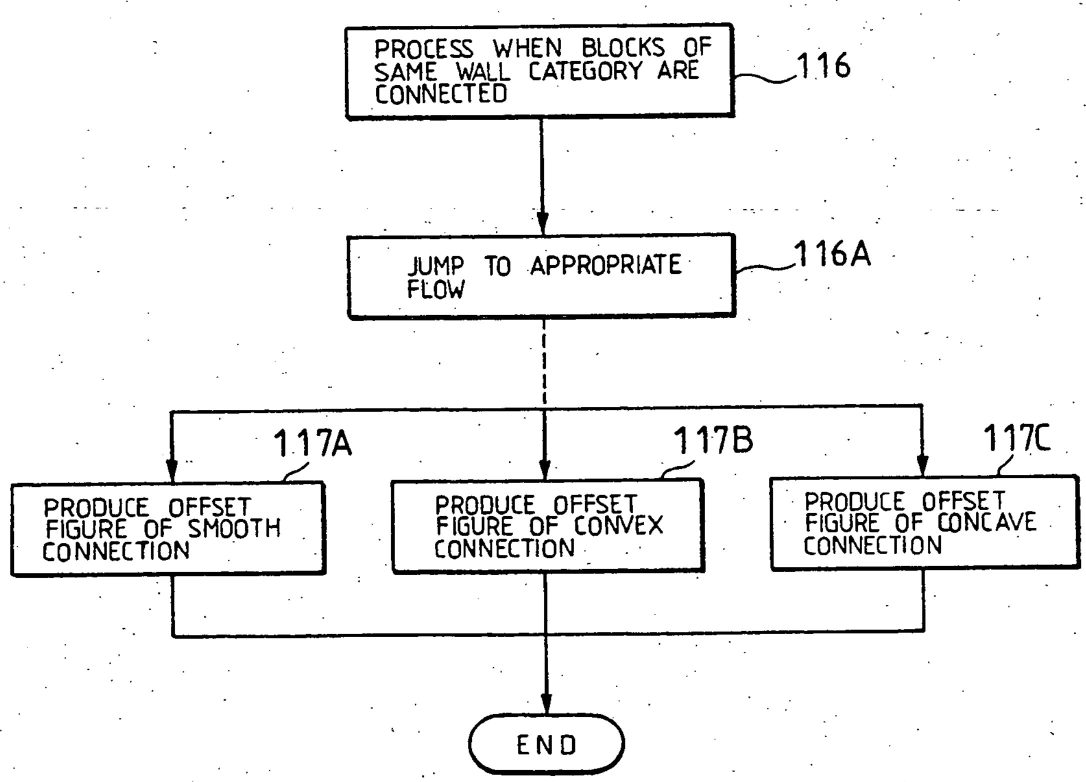

PROCESS WHEN BLOCKS OF SAME WALL CATEGORY ARE CONNECTED
116
JUMP TO APPROPRIATE FLOW
116A
117A
117B
117C
PRODUCE OFFSET FIGURE OF SMOOTH CONNECTION
PRODUCE OFFSET FIGURE OF CONVEX CONNECTION
PRODUCE OFFSET FIGURE OF CONCAVE CONNECTION
END

FIG. 19

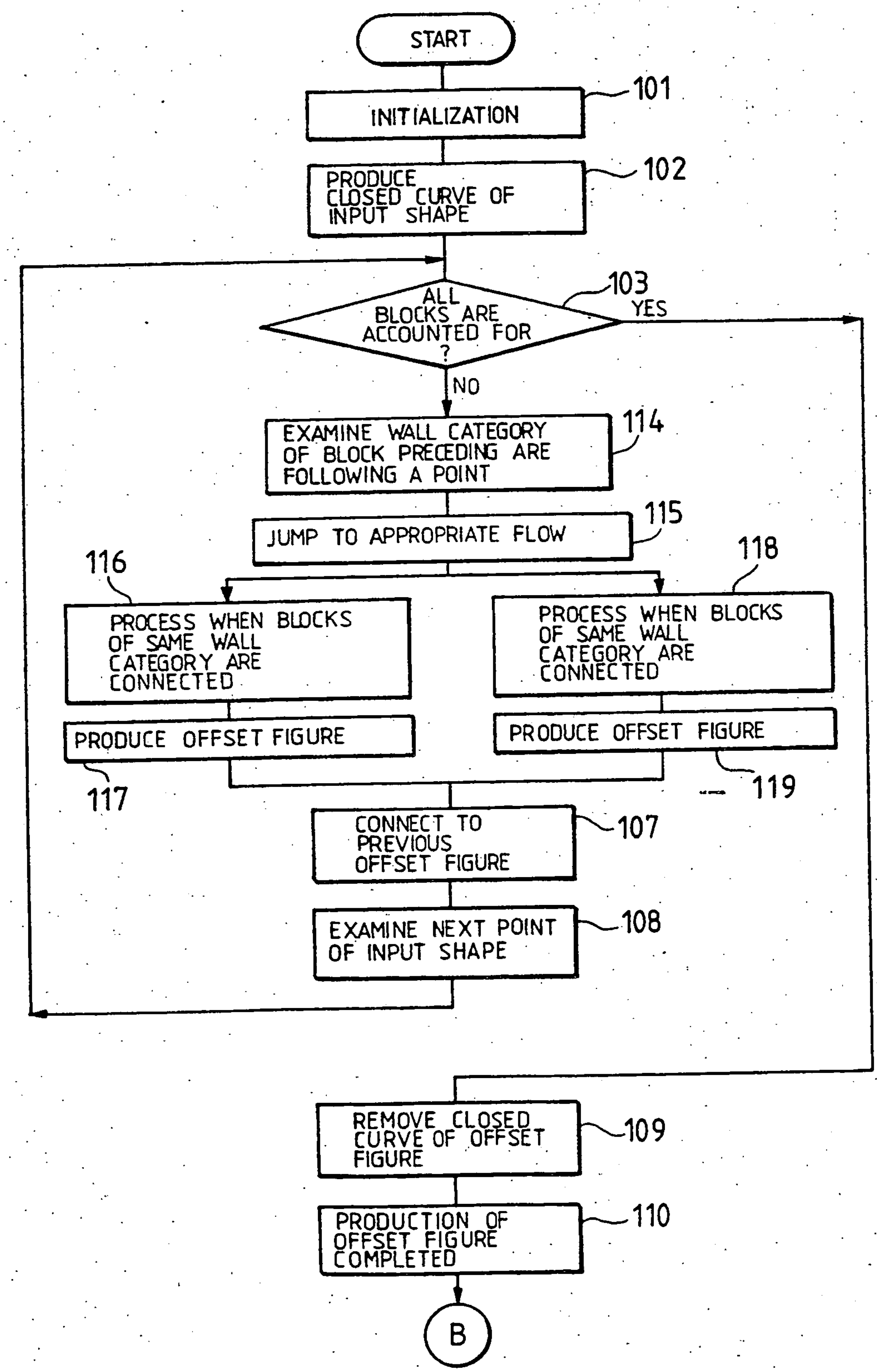

START
INITIALIZATION
101
PRODUCE CLOSED CURVE OF INPUT SHAPE
102
ALL BLOCKS ARE ACCOUNTED FOR ?
103
YES
NO
EXAMINE WALL CATEGORY OF BLOCK PRECEDING ARE FOLLOWING A POINT
114
JUMP TO APPROPRIATE FLOW
115
116
PROCESS WHEN BLOCKS OF SAME WALL CATEGORY ARE CONNECTED
118
PROCESS WHEN BLOCKS OF SAME WALL CATEGORY ARE CONNECTED
PRODUCE OFFSET FIGURE
117
PRODUCE OFFSET FIGURE
119
CONNECT TO PREVIOUS OFFSET FIGURE
107
EXAMINE NEXT POINT OF INPUT SHAPE
108
REMOVE CLOSED CURVE OF OFFSET FIGURE
109
PRODUCTION OF OFFSET FIGURE COMPLETED
110
B

FIG. 21

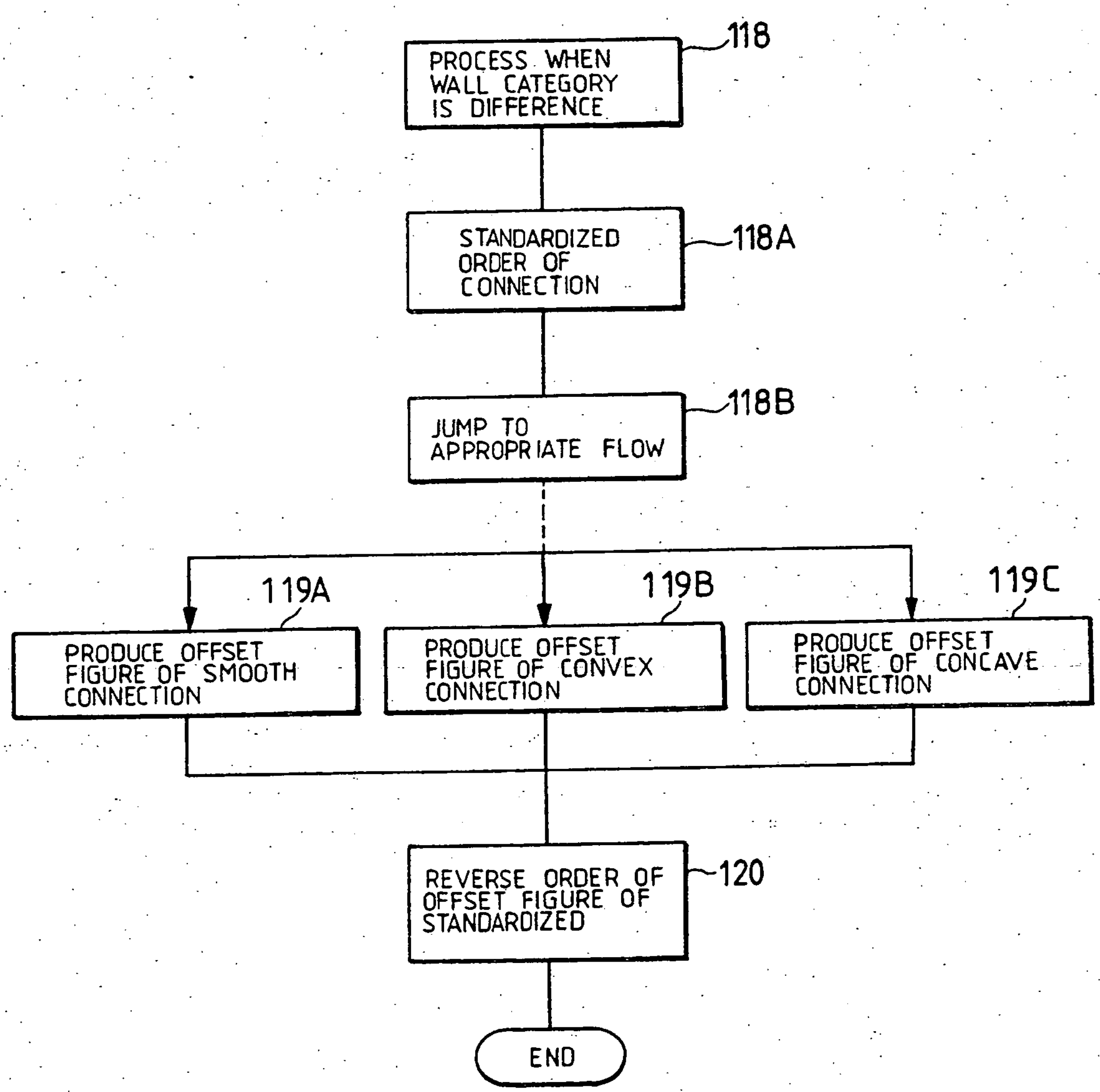

PROCESS WHEN WALL CATEGORY IS DIFFERENCE
118
STANDARDIZED ORDER OF CONNECTION
118A
JUMP TO APPROPRIATE FLOW
118B
119A
119B
119C
PRODUCE OFFSET FIGURE OF SMOOTH CONNECTION
PRODUCE OFFSET FIGURE OF CONVEX CONNECTION
PRODUCE OFFSET FIGURE OF CONCAVE CONNECTION
REVERSE ORDER OF OFFSET FIGURE OF STANDARDIZED
120
END

FIG. 22(a)

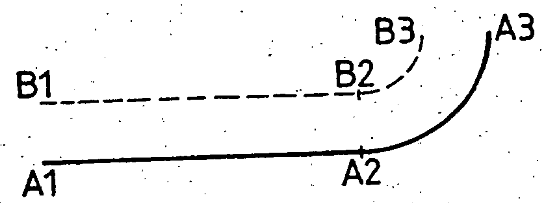


FIG. 23(a)

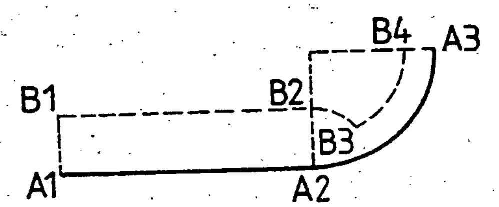


FIG. 22(b)

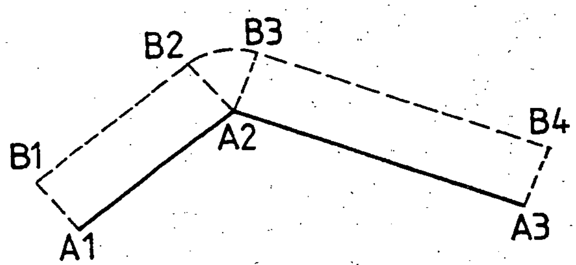


FIG. 23(b)

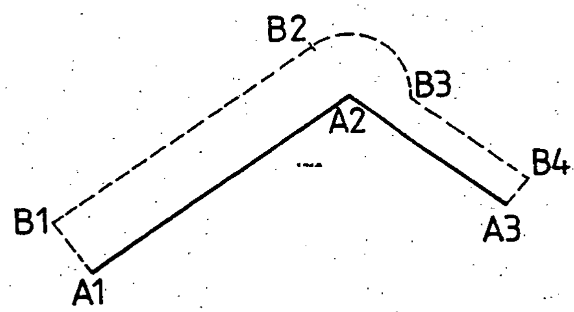


FIG. 22(c)

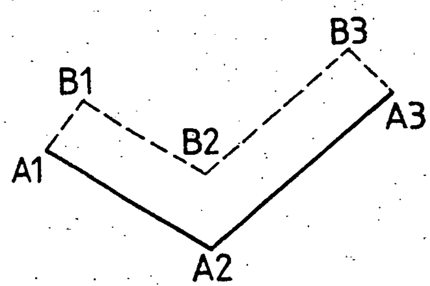


FIG. 23(c)

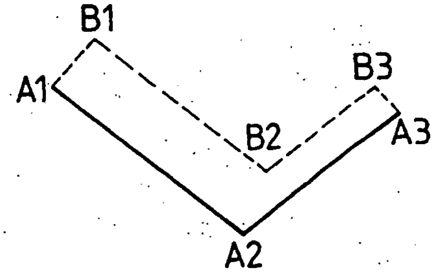


FIG. 24(a)

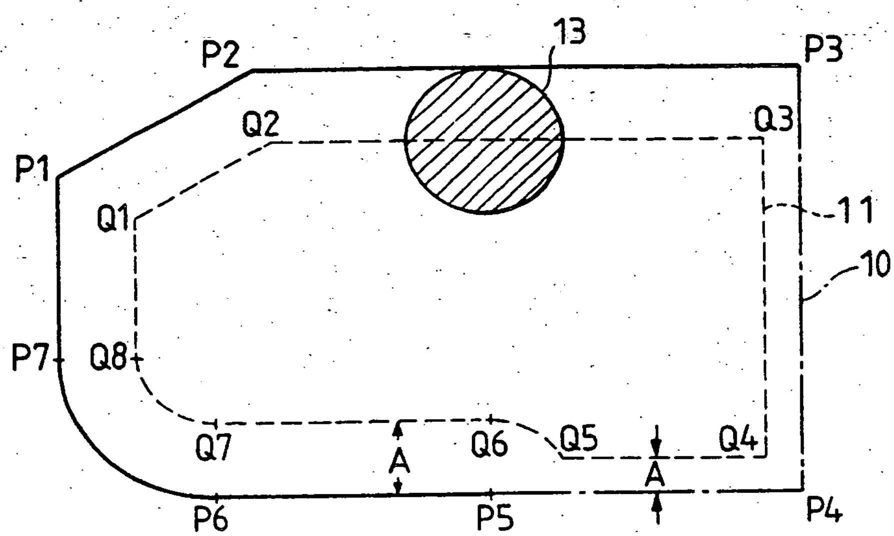


FIG. 24(b)

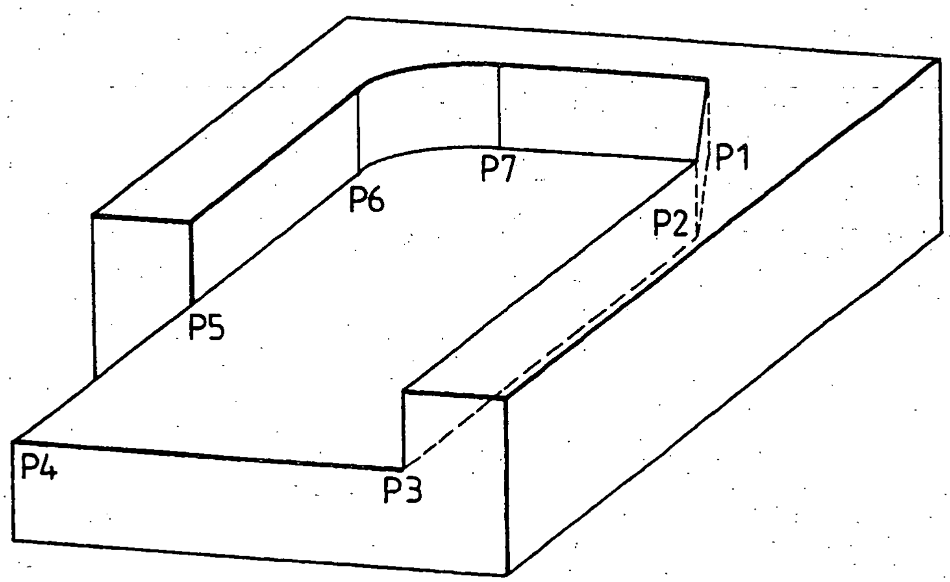


FIG. 25

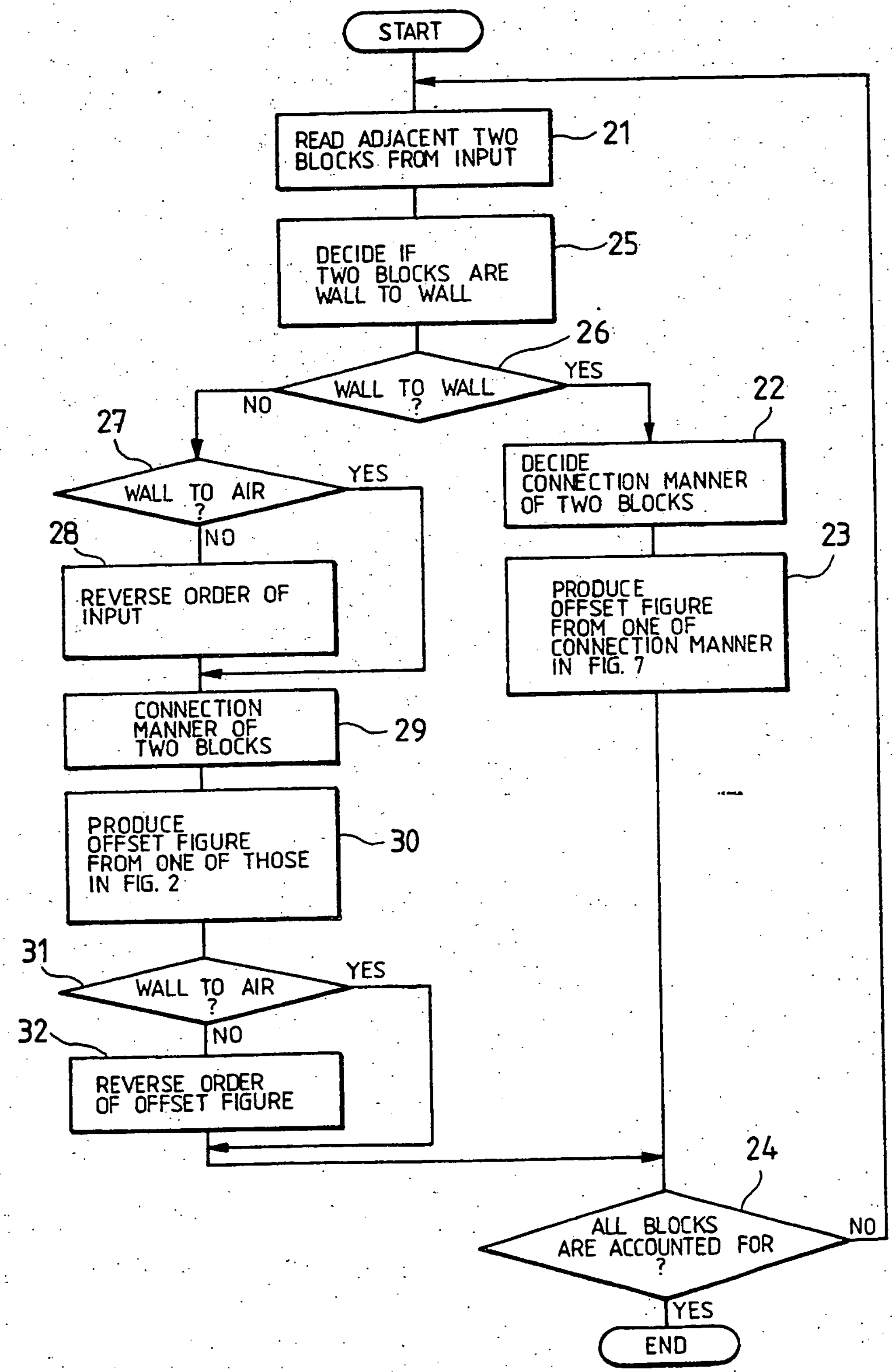

START
READ ADJACENT TWO BLOCKS FROM INPUT
21
DECIDE IF TWO BLOCKS ARE WALL TO WALL
25
26
WALL TO WALL ?
YES
NO
22
DECIDE CONNECTION MANNER OF TWO BLOCKS
27
WALL TO AIR ?
YES
NO
28
REVERSE ORDER OF INPUT
23
PRODUCE OFFSET FIGURE FROM ONE OF CONNECTION MANNER IN FIG. 7
CONNECTION MANNER OF TWO BLOCKS
29
PRODUCE OFFSET FIGURE FROM ONE OF THOSE IN FIG. 2
30
31
WALL TO AIR ?
YES
NO
32
REVERSE ORDER OF OFFSET FIGURE
24
ALL BLOCKS ARE ACCOUNTED FOR ?
NO
YES
END

FIG. 26

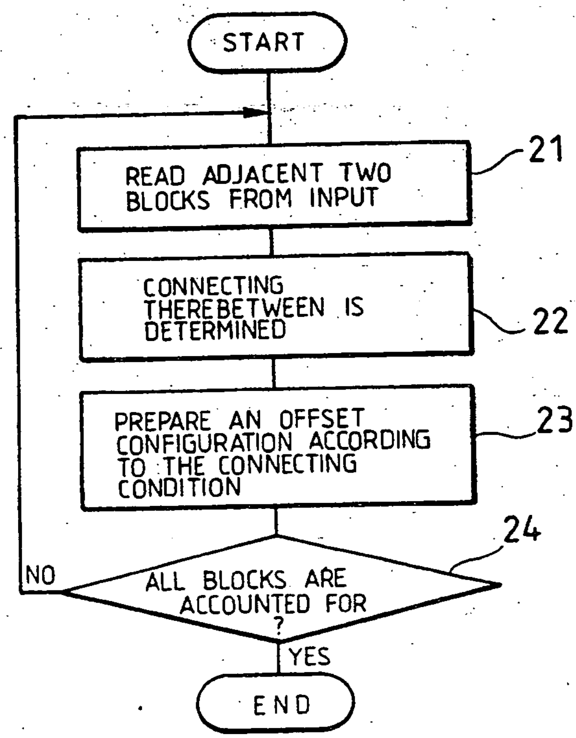
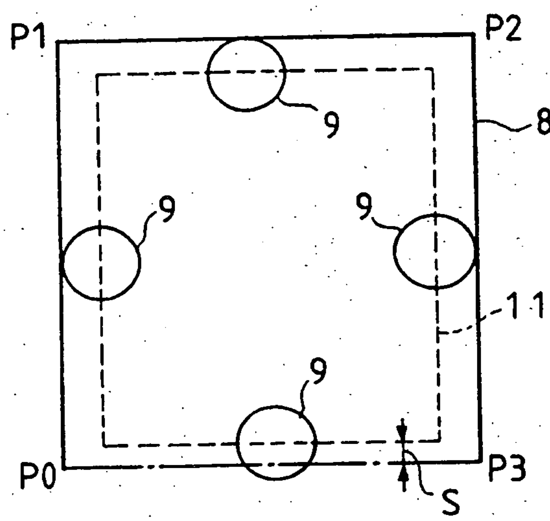

START
READ ADJACENT TWO BLOCKS FROM INPUT
21
CONNECTING THEREBETWEEN IS DETERMINED
22
PREPARE AN OFFSET CONFIGURATION ACCORDING TO THE CONNECTING CONDITION
23
24
NO
ALL BLOCKS ARE ACCOUNTED FOR ?
YES
END

FIG. 27


P1
P2
9
8
9
9
11
9
P0
P3
S

NUMERICAL CONTROL APPARATUS

BACKGROUND OF THE INVENTION

1) FIELD OF THE INVENTION

The present invention relates to a numerical control apparatus having a function which is available in both a closed area (pocket) machining and an open area machining, and more particularly to a numerical control apparatus capable of producing an offset figure for a machining tool, which include both anapproach path to the offset figure and a retract path therefrom.

2) DESCRIPTION OF THE PRIOR ART

A conventional numerical control (NC) apparatus will now be described with reference to Figs. 1(A) to 8(b).

Fig. 1(a) is a schematic diagram for illustrating a workpiece before being machined; Fig. 1(b) is a schematic diagram for illustrating a workpiece after being machined; Fig. 2(a) is a block diagram for showing a hardware of the conventional NC apparatus; Fig. 2(b) is a diagram for showing an input data display on a CRT display shown in Fig. 2(a); Fig. 2(c) is a diagram for showing an input configuration obtained by the input data in Fig. 2(b); Fig. 3 is a diagram for showing data structure in a RAM section of a memory 2 of Fig. 2(a); Figs. 4 and 5 are

flowcharts for the description of an operation of the conventional apparatus; Fig. 6 is a diagram for illustrating an approach path; Fig. 7 is a diagram for showing an example of production of an approach path; and Figs. 8(a) and 8(b) are diagrams for the description of problems accompanying the conventional apparatus.

In Fig. 2(a), reference numeral 1 designates a CPU, and the memory 2 includes a RAM and a ROM which store a control program for controlling the CPU 1 such as a machining program and the like. A key board 3 is used to input into the memory 2 coordinates of an ultimate machined configuration of a workpiece, data for machining and the like, and a CRT 4 displays machining programs and picture images as shown in Fig. 2(b). A servo mechanism 5 converts displacement data from the CPU into the number of pulses for actually driving a servo motor 6, and a machine tool 7 includes the servo motor 6.

An operation of the conventional apparatus will now be described as follows. The display 8 shown in Fig. 2(b) is first selected and displayed on the CRT display 4. The ultimate machined configuration 9 of a workpiece as shown in Fig. 2(c) is input in the form of coordinates together with machining conditions such as data of tools to be used.

When a tool path provision key is pressed after all the data is input, the CPU 1 calculates the center of an arc and so on to be stored in the form of data structure as shown in Fig. 3a in the RAM of the memory 2.

In Fig. 3(a), a flag is data of about two bytes representing the category of a block, for example in the form of data structure shown in Fig. 3(b). The variables x and y represent, respectively, coordinates of terminal points of blocks such as a line and an arc, each variable being of 4 or 8 byte data depending on the system. In case of the block being an arc, the variables in i and j indicate the X and Y coordinates of the center of the arc, and k indicates a radius thereof. In case of the block being a straight line, the variables i, j, and k are assigned to either no-meaning or an equation representing the straight line.

In the case where a workpiece 10 as shown in Fig. 1(a) is to be machined to have a ultimate configuration showing in Fig. 1(b), input data for points P1 to P7 are stored in the memory 2 in the form of data structure shown in Fig. 3(a).

Then an offset locus 11 which represents a locus of the center of a machining tool, is produced as shown in Fig. 10(a). An offset figure (locus) 11 is formed, as shown in Fig. 7, by connecting points Q1 to Q7 which are

offset inwardly by an offset value equal to the radius of the tool used. The offset figure is a border line beyond which the center of the machining is prevented from going. An approach path 12 is produced with respect to this offset figure 11 according to an operation flow shown in Figs. 4 and 5.

In Fig. 4, such convex points that an angle of a portion to be machined exceeds 180 degree, are searched in the closed curve of the offset figure 11 (step 101). If the convex point is found, then it is decided whether or not it is possible to approach the point (step 102). If possible, an approach path for entering a point next to the point perpendicularly thereto is produced as shown in Fig. 6a (step 103). The term of "impossible to approach" means that the length of that block (e.g. Q1-Q2, Q2-Q3, ..., Q7-Q1 in Fig. 7) is shorter than the radius of the tool, for example. If approaching to the convex point is impossible, the searching operation is carried out to find the next convex point. The reason why the convex point is first searched, is because a load to a machining tool is lowest in such an approach to the convex point. In the case where there is no convex point or there are no points to which the approaching is possible, then the searching operation is started to find a point that is located at smoothly curved portion of the closed curve

(step 104). If a point that is located at smoothly curved portion thereof is found, then it is decided whether or not it is possible to approach the point (step 105). If possible, an approach path 12 is produced as shown in Fig. 6(b) (step 106). It should be noted that the reason why the smooth portion within the closed curve is searched secondly is because the load to the machining tool is relatively lower than the other portions.

If the approach path 12 cannot be produced through the aforementioned steps, it means that either there are only concave points or there are only points to which the approach paths cannot be produced. Then, it is decided whether or not there is a boundary between two concave points (step 107). If there is a boundary therebetween, it is decided whether or not it is possible to approach that point (step 108). If possible, then an approach path is produced as shown in Fig. 6(c) (step 109).

In the case where no approach paths can be still produced through the aforementioned steps, it is decided whether there occurs an error in the approaching. This error means that the size of a workpiece to be machined input per se is too small to approach thereto.

In the case where an ultimate workpiece shown in Fig. 1(b) is to be machined from a workpiece shown in Fig. 1(a), since the point P3 is a convex point, such an

approach AP1·Q3 as shown in Fig. 7 is produced. Then tool paths and other machining information are produced and then machining information are output to the servo mechanism 5 for controlling the machine tool 7 to perform the machining of a workpiece.

With a conventional numerical control apparatus thus constructed, the approach path 12 is obtained without taking wall category of an ultimate shape into account, and therefore it is disadvantageous in that, in case of machining a workpiece having a configuration as shown in Fig. 8 for example, due to the point AP being convex, there is a possibility that an approach path AP1·AP or AP2·AP may be produced resulting in an occurrence of interference between the tool and the workpiece.

SUMMARY OF THE INVENTION

In view of the above difficulties accompanying the prior art, it is an object of the present invention to eliminate the difficulties accompanying the prior art systems and to provide a numerical control apparatus capable of producing an offset figure for a machining tool, which include both approach and retract paths therefor, based on input data for an ultimate machined configuration and one wall category without need of providing various machining modes in an area machining or pocket machining.

The above and other objects of the present invention is met to the provision of a numerical control apparatus which produces an offset figure for a machining tool and an approach/retract path therefor on the basis of an input data to perform contour-machining comprising: means for inputting wall category of wall blocks in an ultimate machined condition of a workpiece; and means for producing an offset and an approach/retract path on the basis of the wall category of the wall blocks.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

Fig. 1(a) is a diagram for showing a specific workpiece before it is machined;

Fig. 1(b) is a diagram for the specific workpiece after it is machined;

Fig. 2(a) is a diagram for showing a hardware circuit arrangement;

Fig. 2(b) is a diagram for showing an input picture;

Fig 2(c) is a diagram for showing an input of a workpiece;

Fig. 3(a) is a diagram for showing a data structure of RAM section of a memory;

Fig. 3(b) is a diagram for illustrating a flag portion of Fig. 13a;

Fig. 4 and Fig. 5 are flowcharts for illustrating

Fig. 6 is a diagram for illustrating how an approach path is produced;

Fig. 7 is a diagram for showing a specific example of how an approach path is produced;

Fig. 8 is a diagram for illustrating deficiencies of a prior art apparatus;

Fig. 9(a) is a diagram showing an example of numerical control apparatus according to the present invention, which is substantially same as the conventional apparatus;

Fig. 9(b) is a diagram illustrating an example of a display of an input data;

Fig. 9(c) is a diagram illustrating an ultimate machined configuration of a workpiece obtained according to the input data shown in Fig. 9(b);

Fig. 10(a) is a diagram for illustrating how an offset shape is produced;

Fig 10(b) is a diagram for illustrating how a specific example of an approach path/retract path is produced;

Fig. 11(a) is a diagram for showing data structure of RAM section of a memory;

Fig. 11(b) is a diagram for illustrating a flag portion of Fig 11(a);

Fig. 12 to Fig. 14 are flowcharts for illustrating operation of producing an approach;

Figs. 15(a) to 15(e) are diagrams for illustrating how an approach path is produced;

Fig. 16 and Fig. 17 are flowcharts for illustrating operation of producing an approach;

Fig. 18 is a diagram for illustrating a specific example of producing an approach path/retract path;

Figs. 19 to 21 show flow charts for an operation for forming an offset figure;

Figs. 22(a) to 22(c) are diagrams showing an offset figure;

Figs. 23(a) to 23(c) are diagrams showing the connecting condition between two wall blocks;

Figs. 24(a) is a diagram showing an offset figure;

Fig. 24(b) is a schematic diagram showing a workpiece machined;

Fig. 25 is a flow chart for another embodiment of the present invention;

Fig. 26 is a flow chart for the other embodiment of the present invention; and

Fig. 27 is a diagram showing an offset figure.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A first preferred embodiment will now be described with reference to Figs. 9(a) to 15(c). Fig. 9(a) is a

diagram showing an example of numerical control apparatus according to the present invention, which is substantially same as the conventional apparatus. Fig. 9(b) is a diagram illustrating an example of a display of an input data. Fig. 9(c) is a diagram illustrating a ultimate machined configuration obtained by the input data shown in Fig. 9(b). Fig. 10(a) is a diagram illustrating the production of an offset figure and Fig. 10(b) is a diagram an example of an approach path. Figs. 11(a) and 11(b) are diagrams for showing an example of data structure stored in a RAM section of a memory. Figs. 12 to 14 are flowcharts for the operation of the control apparatus and Figs. 15(a) to 15(c) are explanatory diagrams for an approach path.

Elements similar to or identical to those of the conventional apparatus bear the same or corresponding reference numerals throughout the drawings.

A display 8 is first selected and displayed on a CRT display 4 as shown in Fig. 9(b). As is apparent from Fig. 9(b), the display 8 is adapted to include data as to wall category ("A" or "W") of a workpiece. The A denotes an air wall and the W denotes a real wall. The wall category "A" means a terminal point of a block like such as P7·P1 or P1·P2 where the tools are allowed to go beyond the boundary while the wall category "W" means a terminal

point of a block such as P2·P3, P3·P4, P4·P5, P5·P6 and P6·P7 where the tools are prevented from going beyond the boundary.

An operator inputs, by means of a key board 3, an ultimate machined configuration 9 of a workpiece as shown in Fig. 9(c) in the form of coordinate values as well as tool data, where the respective coordinate values represent the terminal points of the respective block. In addition, the wall categories for the blocks are also input to the data shown in Fig. 9(b).

The CPU 1 produces data as to the respective points in the form of data structure shown in Fig. 11(a) as in the conventional apparatus. In this case, flag bits, for example a most significant bit is assigned to indicate the wall category. A logic level, for example logic level "1" indicates the real wall "W" whereas a logic level "0" indicates the air wall "A".

An offset figure 11 is formed within the ultimate machined configuration 9 as shown in Fig. 10(a) taking the radius of the tool, wall category and so on into consideration, the offset figure 11 being obtained by connecting points Q1 to Q7 that are offset from the ultimate machined configuration 9 by an offset value equal to the radius of the tools at the real walls and by an

offset not more than the radius of the tools at the air walls.

An example of the formation of the offset figure 11 will be described with reference to Figs. 19 to 21 showing flow charts for an operation for forming the offset figure. In Figs. 19 to 21, the apparatus is initialized (step 101); a closed curve for an ultimate machined configuration 10 is formed by repeating the data processing of the input data (step 102); It is detected whether an offset figure with respect to the thus formed ultimate machined configuration is completed or not (step 103; The wall category of a wall preceding and following a point is examined (step 114); then the program jumps to an appropriate flow depending on the wall category thereof (step 115).

In the case where the blocks having the same wall category are continuously connected, steps 116 and 117 are carried out. On the other hand, in the case where blocks having different wall categories are continuously connected, step 118 and 119 are carried out. The process for the same type blocks, that is, Air-to-Air or Wall-to-Wall (referred to merely as A-A or W-W when applicable) is carried in accordance with a flowchart shown in Fig. 20. The program jumps to an appropriate flow depending on the connecting condition of the blocks (step 116A). Then if

the connecting condition is smooth, an offset figure is formed within the ultimate machined configuration by an offset equal to the radius of a tool (when W-W connection) or substantially equal to a half of the radius of a tool (when A-A connection) as shown in Fig. 22(a) (step 117A); an offset figure is formed within the ultimate machined configuration with an offset equal to the radius of a tool (when W-W connection) or substantially equal to a half of the radius of a tool (when A-A connection) as shown in Fig. 22(b) if the connecting condition is convex (step 117B); and an offset figure is formed within the ultimate machined configuration by an offset equal to the radius of a tool (when W-W connection) or substantially equal to a half of the radius of a tool (when A-A connection) as shown in Fig. 22(c) if the connecting condition is concave (step 117C).

In the case where the blocks of different wall categories are connected (W-A, or A-W), the process is carried out as shown in Fig. 21. That is, the order of connecting points of the respective blocks are standardized (step 118A), thereafter the program jumps to an appropriate flow depending on how the block is connected to a preceding block or a following block (step 118B). Then, an offset figure is formed within the ultimate machined configuration at an air wall A with an

offset generally equal to a half of the radius of a tool as shown in Fig. 23(a) if the connecting condition is smooth (step 119A), an offset figure is formed at the air wall A within the ultimate machined configuration with an offset generally equal to a half of the radius of a tool as shown in Fig. 23(b) if the connection is convex (step 119B); and an offset figure is formed within the ultimate machined configuration at the air wall A with an offset generally equal to a half of the radius of the tool if the connection is concave. Finally, the blocks whose order of connection have been standardized are reversed the order thereof (step 120).

The reason why the order of the connecting points of the respective blocks are standardized by rearranging the order of A-W to W-A for example in the step 118A is because it is made possible to carry out the formation of the offset figure more easily.

The further steps of the process is of the same as those in the conventional apparatus and thus a detailed description therefor is omitted intentionally.

Consequently, the offset figure formed through the steps described above is a figure in which the real wall section such as P5 to P3 is offset within the ultimate machined configuration by an offset equal to the radius of a tool, and the air wall section such as P3 to P5 is

offset within the ultimate machined configuration by an offset equal to a half of the radius of the tool. The tool path 14 is produced on the basis of this offset figure. Accordingly, the workpiece can be machined to have a desired configuration without any portion thereof left uncut as shown in Fig. 24(b).

An approach path is produced with respect to the offset figure 11 in accordance with a flowchart as shown in Figs. 12 to 15(c).

In Fig. 12, an air block in the closed curve of the offset figure 11 is first searched (step 110). If the air block exists, then it is decided whether it is possible to approach the air block or not (step 111).

The case where it is impossible to approach the air block means that the length of the air block is shorter than the radius of the machining tool.

If "YES" in the step 111, that is it is decided that it is possible to produce an approach path, an approach path is produced to the block (step 112). This production of the approach path will be described in detail with reference to Fig. 13. If an air block is found, it is detected whether or not the block is connected to the next block at a concave point (step 111A). If "YES", that is the block forms a concave portion with the following block, it is decided whether or

not it is possible to produce an approach path (step 111B). If it is possible to produce such an approach path, the approach path is produced to enter the next block perpendicularly. In other words, The approach path is produced on an extended line of the offset figure 11 to the next block as shown in Fig. 15(a) (step 112A).

In the case where it is decided that an approach path cannot be produced at the steps 111A and 111B, it is decided whether or not there are any connecting points other than the concave point at the terminal end point of the air block (step 111C). If such a point is found, it is detected whether or not it is possible to approach that point (step 111D). If "YES", that is, if it is possible to approach, a quarter arc of a circle having the same radius as that of the tool is produced from the air block as an approach path as shown in Fig. 15(b). The starting point of the arc may be extended as shown in Fig. 15(c).

If the approach path to the air block cannot be produced, the approach path is produced in the same manner as the conventional apparatus (step 101 to 109).

If the formation of the approach path to a certain point is impossible, a searching operation for a convex point is then started. If no convex point is found in the closed loop configuration or there are no convex points to which the approach path can be produced, a searching

operation for a smooth portion is then started. If a point in a smooth portion to which the approach is possible, is found, an approach path is produced as shown in Fig. 15(d) is produced. If there is no smooth portion, it means that there are only concave points or points impossible to approach in the closed loop configuration. In this case, the approach is attained to a mid point of consecutive two points as shown in Fig. 15(e).

Fig. 10(b) is a diagram showing the tool path including the approach path which are produced in accordance with the steps described above. In Fig. 10(b), AP1 denotes an approach point when machining is performed in the direction of CCW (counterclockwise) and AP2 denotes an approach point when machining is performed in the direction of CW (clockwise).

Although the formation of an approach path is only discussed in the above first embodiment, the present invention is available to a retract path (a locus of a tool when leaving the workpiece after machining of a block is completed). In such a case, a retract path may be produced in the form of a path perpendicular to or a quarter arc which starts from the block preceding the air block that is approached. For example, if the machining is performed in the CW direction, AP2·Q2 is an approach path and $\bar{Q}7$·AP1 is a retract path in Fig. 10(b). As is

clear from the above, the present invention permits producing of approach paths in which there occurs no interference between the tools and the workpiece to be machined.

The first embodiment may have disadvantage that an approach path which results in waste in cutting period of time may be produced depending on the configuration of a workpiece.

An example of the approach path for a workpiece shown in Fig. 1(b) is as shown in Fig. 10(b). In such as example, the travelling of the tool from the point AP2 to Q2 in the CW machining direction and the travelling of the tool from the point AP1 to Q7 in the CCW machining direction are carried out under a so-called "Air-cutting" condition. This results in elongation of machining period of time.

In such cases, the elongation of the machining period of time can be prevented by the formation of the approach path as shown in Fig. 18. In Fig. 18, the approach point is positioned at a start point of a wall block connected to the terminal point of an air block. More specifically, in Fig. 18, assuming that Q1 is the start point, the point Q2 is the terminal point of the air wall block as well as the start point of the real wall block if the machining is performed in the CW direction

whereas the point Q7 is the terminal point of the air wall block as well as the start point of the wall block if the machining is performed in the CCW direction. The formation of an approach path as shown in Fig. 18 can be carried out according to the operation shown in Figs. 16 and 17.

In Fig. 16, it is detected whether or not an air block followed by a wall block exists within a closed curve of an offset figure 11 (step 113). If such a block exists, it is decided whether or not it is possible to approach that block (step 114). The fact that it is impossible to approach the block means that the diametical distance (indicated by a dotted line in Fig. 18) to the terminal point of the wall block before the air block of interest is shorter than the diameter of the tool.

Referring to Fig. 17 which shows steps for producing an approach path, if an air block followed by a wall block (air wall to real wall block) is found, it is detected whether or not the air block is connected to the wall block at a concave point (step 114A); if such a point exists, it is decided whether or not it is possible to produce an approach path leading to the block (step 114B). If it is possible to produce the approach path, an approach path is produced to enter the wall block perpendicularly thereto as shown in Fig. 15(a), in other

words on a extended line of the offset shape of the wall (step 115A).

A decision that the formation of an approach path is impossible in the steps 114A and 114B, means that one block is smoothly connected to the other. In this case, it is detected whether or not it is possible to produce an approach path to the block (step 114C). If it is possible to produce an approach path, a quarter arc of a circle having the same radius as the tool which starts from the air block, is produced as an approach path as shown in Fig. 15(b). The start point of the arc may be extended further as shown in Fig. 15(c).

Fig. 18 is a diagram showing a tool path including approach path which is produced in accordance with the steps shown in Figs. 16 and 17. In Fig. 18, AP1 denotes an approach point if the machining is to be performed in the CW direction and AP2 denotes an approach point if the machining is to performed in the CCW direction. In the case where the approach path cannot be produced, then the apparatus attempts to produce an approach path in accordance with steps of the first embodiment previously described, and if the approach path still cannot be produced, the approach path will be produced in the same manner as the conventional apparatus.

CLAIMS

(1) A numerical control apparatus which produces an approach path/retract path on the basis of an input data to perform contour-machining, comprising:

means for inputting wall category of wall blocks in an ultimate machined condition of a workpiece;

means for producing an approach/retract path on the basis of the wall category of the wall blocks.

(2) A numerical control apparatus as defined in claim (1) where said approach/retract path producing means produces the approach/retract path to a convex portion of an ultimate machined configuration of the workpiece.

(3) A numerical control apparatus as defined in claim (2) wherein said approach/retract path producing means produces the approach/retract path to a smooth portion of the ultimate machined configuration in case of no convex portion thereof.

(4) A numerical control apparatus as defined in claim (2) wherein said approach/retract path producing means produces the approach/retract path to a mid point of one of the wall blocks in case of no convex portion and no smooth portion thereof.

Although the formation of the approach paths is discussed in the aforementioned second embodiment, the embodiment can also be applied to producing retract paths. A connecting point between an air block preceded by a wall block and the wall block is searched, and then a retract path is produced with respect to that connecting point. For example in Fig. 18, AP1·Q2 is an approach path and Q7·AP2 is a retract path.

According to the present invention, an offset machining path and an approach/retract path for machining tools are produced on the basis of wall category of a workpiece thereby resulting in preventing an occurrence of interference between the tools and the workpiece. Further, an approach path can be produced at a portion where actual cutting takes place, and thus a numerical control apparatus having a short machining time can be implemented.

(5) A numerical control apparatus which produces an approach/retract path on the basis of input data to perform contour-machining, comprising:

means for inputting wall category of a workpiece;

means for reading an air wall block of said wall category of the workpiece;

means for deciding whether or not an approach/retract path can be produced to said air wall block upon the detection of an air wall block; and

means for producing an approach/retract path to said air wall block if it is decided that said approach/retract path can be produced.

(6) A numerical control apparatus which produces an approach/retract path on the basis of an input data to perform contour-machining, comprising:

means for inputting wall category of a workpiece;

means for searching an air-wall-to-real-wall block based on said wall category of the workpiece;

means for deciding whether or not an approach/retract path can be produced to the air-wall-to-real-wall block when the air-wall-to-real-wall block is detected; and

means for producing an approach/retract path to the air-wall-to-real-wall block if it is decided that the

approach/retract path can be produced to the air-wall-to-real-wall block.

(7) A numerical control apparatus for machining a workpiece to have an ultimate machined configuration having a concavity which opens at a portion thereof, comprising:

means for inputting data for machining;

means for producing an offset figure with an amount of offset from the ultimate machined configuration; and

means for producing a tool path based on an output of said offset figure producing means;

the amount of offset being varied in accordance with wall category of said workpiece in the ultimate machined configuration.

(8) A numerical control apparatus according to Claim (7), wherein said offset figure producing means comprises means for detecting whether the wall category of a workpiece which is input by said inputting means is a real wall or an air wall and means for producing the offset figure in which the offset amount in the air wall is set less than the offset amount in the real wall.

(9) A numerical control apparatus having an area machining function comprising:

means for inputting first data as to an ultimate machined configuration of a workpiece, which has a concaved portion;

means for reading the data to obtain second data as to two adjacent wall blocks of the concaved portion;

means for deciding based on the second data whether the connection between said two wall blocks is wall-to-wall or not;

means for processing the blocks as a closed area if the connection is wall-to-wall;

means for deciding whether the connection between said two wall blocks is wall-to-air or not if the connection is not wall-to-wall;

means for determining the order of connection between a wall and air and manner of the connection; and

means for processing the blocks as an open area if the connection is wall-to-air.

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